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# Annotated Bibliography of Camping Market Surveys







USDA FOREST SERVICE GENERAL TECHNICAL REPORT NE-11
1974

NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
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**Abstract**

A compendium of more than 200 published and unpublished surveys and observational studies of campers conducted between 1936 and 1973. The majority of citations are American and Canadian. Selected findings are reported for each study. The bibliography is organized in five categories: national, regional, local, readership, and miscellaneous surveys.

# INTRODUCTION

CAMPING AND recreational vehicle travel in America have become major outdoor recreation markets. The change in campground ownership patterns — from a near monopoly in public ownership in the late 1950's to private enterprise supremacy today — has created an urgent demand for factual information about the camping market, its trends and its opportunities. In 1973, it was estimated that 60 percent of the Nation's 15,000 campgrounds were run by private enterprise; and that one out of every two Americans was an active camper, an ex-camper, or a potential camper.

As camping's popularity grew, and camping styles changed, campers became the subjects of a wave of survey research by public outdoor recreation agencies, by potential investors, by state planning groups, and university researchers and their graduate students. The total number of published and unpublished studies, by 1973, exceeded 200.

This bibliography is an attempt to catalog and describe as many of those surveys as possible. The annotations for each survey are not intended to represent complete abstracts, or even to identify every major finding. Emphasis in abstracting findings is on those items of camper behavior that are likely to trend over time: annual camping frequencies, percent of the sample who are in their first year of camping, the type(s) of camping equipment in use, average daily expenditures while camping, and camper observations about crowding and environmental change.

Where possible, each annotation includes: the year in which the survey was conducted; the method of data collection — interviews, questionnaires, or observations — and the size of the sample(s); the locale in which the data were collected; and the major findings. Recurrent findings, such as the size of camping parties (three to five persons) and the "higher than average" incomes of camping families, are not abstracted. Findings which are highly subject to local variation, such as length of visit, are not included except as state or region-wide totals.

The bibliography is assembled into 5 broad categories of surveys: I. national surveys, II. regional and state surveys, III. local surveys of visitors to specific parks and forests, IV. magazine readership and camping association memberships surveys, and V. miscellaneous reports of surveys and observational studies related to camping.

# PART I. NATIONAL SURVEYS

1. Anonymous.
1972. **Leisure Boom: Biggest Ever and Still Growing.** U.S. News and World Report, April 17: 42-45.

Describes American expenditures for leisure activities. Refers to a 1971 Bureau of Outdoor Recreation Survey which identifies the most popular outdoor activities; camping ranked ninth with 35.2 million participants, or 21 percent of the population 9 years of age or older. See No. 10.

2. Canadian National Park Service.
1971. **1971 Statistical Reference on Visitation, the User and Use.** National Park Service—Planning, Dep. of Indian Affairs and Northern Develop. Ottawa, Canada.

A lengthy (over 1,000 unnumbered pages) compilation of Canadian National Parks visitor characteristics, from several sources: (1) A questionnaire survey of approximately 4,000 visitors to six Canadian National Parks in 1971. Provides a detailed summary, by parks, of party composition, party size, party origin, visit length, accommodation equipment carried, guest accommodations used, and activities participated in. Also presents a detailed comparison of users and non-users of park interpretive facilities. (2) An interview survey of American visitors leaving Canada in 1968, concerning their reasons for visiting Canada, trip destinations, expenditures in Canada, visits to national parks, and socioeconomic and demographic characteristics. (3) An interview survey of Canadian residents, 18 years of age and older, in 1967, 1968, and 1969, to determine their use of Canadian National Park facilities. Gives participation rates for several outdoor recreation activities, including camping (21 percent of the males and 20 percent of the females); and compares park users with non-users in terms of their demographic and socioeconomic characteristics.

3. Ferriss, Abbott L., Betty C. Churchill, C. H. Proctor, and Lois E. H. Zazove.
1962. **National Recreation Survey.** Outdoor Rec. Resources Review Comm. Study Rep. 19. 394 p. U.S. Govt. Print. Off., Washington, D.C.

National sample interview survey of 17,480 persons 12 years of age and over conducted between September 6, 1960 and June 16, 1961, by the Bureau of the Census. Reports outdoor recreation participation rates by activity and region, according to age, sex, race, occupation, education, and place of residence. Includes a section on camping. Eight percent of the population, an estimated 10.4 million persons, camped one or more times during June, July, and August, 1960. Correlates camping activity with other outdoor activities, and describes campers according to the above demographic and socioeconomic characteristics.

4. Guinee, Bert T.
1972. **Today's Campers and What They Want.** Campground & RV Park Manag. 3(5): 1, 8-9.

See No. 14.

5. Hendee, John C.
1969. **Rural-Urban Differences Reflected in Outdoor Recreation Participation.** J. Leisure Res. 1(4): 333-341.

Reports differences in participation rates for several outdoor recreational activities according to rural versus urban residence. Rural area residents were found to camp more than urban area residents. Data drawn from the 1960 National Recreation Survey conducted by the Outdoor Recreation Resources Review Commission.

6. Kampgrounds of America, Inc.
1971. **Profile of The Family Camper. . . . a survey of campers who registered at KOA Kampgrounds.** Camping Market Data, KOA Handb. and Dir. for Campers. 6 p.

Questionnaire survey of 262 campers visiting KOA campgrounds during 1971. Twenty-five percent camped from 1 to 14 days during the preceding 12 months, 29 percent camped from 15 to 29 days, 34 percent camped from 30 to 59 days and 13 percent camped more than 60 days. Twenty-four percent own a tent, 18 percent a camp trailer, 33 percent a travel trailer, 24 percent a truck camper and 6 percent a motor home. Three percent of the families had been camping for less than 2 years. Also presents information on camping mileage during the past year; distribution of camping activity by months; age of equipment and purchasing intentions, and camper ages, education, incomes, occupations, and size of city of origin.

7. Kampgrounds of America, Inc.
1973. **KOA 1972 Camper Survey.** Smoke Signals (7(4): 8-12. KOA., Billings, Mont.

Based on a questionnaire survey of 594 randomly selected KOA customers in 1972. Item by item comparisons are made between 1972 results and a similar 1971 survey. In 1972, 38 percent used a travel trailer while camping, 22 percent a tent trailer, 14 percent a truck camper, 6 percent a motor home, 5 percent a van conversion, and 12 percent a tent. Thirty-five percent prefer to camp in State or National *Parks* while on a typical camping vacation trip; 16 percent prefer State or National *Forests* and 45 percent prefer private campgrounds. Forty-six percent go to a specific location and stay there for their camping vacation, while 54 percent prefer to move frequently. Twenty-one percent of the campers have rented some type of camper vehicle, and 96 percent of these rented the equipment before leaving home. Four percent went on their first camping vacation in 1972. Presents a detailed profile of KOA campers, their demographics, camping patterns, preferences, experiences, expenditures, sources of information, credit-card use, equipment ownership, and purchasing intentions.

8. LaPage, Wilbur F.
1973. **Growth Potential of the Family Camping Market.** USDA Forest Serv. Res. Paper NE 252. 25 p. NE. Forest Exp. Sta., Upper Darby, Pa.

Based on interviews with 2,003 heads of households in a 1971 nation wide sample. Nineteen percent of the sample, or an estimated 12.6 million households had camped during the past year; another 14 percent had camped, but not in the past 12 months; and 15.3 percent thought that they might try camping in the future. For their most recent trip, 11 percent of all campers had rented their equipment, and 35 percent had borrowed it. Campers who had been in the market for at least two years were asked if their camping participation had been increasing or decreasing during the past few years. Only 16 percent reported an increase, as opposed to 37 percent who reported decreasing participation and 25 percent whose participation was either constant or highly variable. For their most recent trip, about half the campers used tents and half used some type of camping vehicle. Among the non-camping households who expressed a desire to start camping, 25 percent indicated a preference for tents, and 63 percent expect to use some type of camping vehicle. At least 51 percent of the households sampled had little or no interest in camping.

9. McKelvey, John.
1973. **Profiling the Leisure Industry and the U.S. Camper.** Midwest Res. Inst. Rep. 1114. 28 p. Kansas City, Mo.

Interview survey of over 5,000 randomly selected households across the United States, in 1971. An estimated 10 percent of the population went camping in tents in 1970, and 12 percent camped with trailers or other recreational vehicles. Tent campers averaged six outings, and trailer campers twelve, in 1970. Presents regional breakdowns of both types of camping, and demographic descriptions of the participants in both camping styles. Also describes other leisure activities of campers.

10. Mandell, Lewis and Robert W. Marans.
1972. **Participation in Outdoor Recreation: A National Perspective.** 88 p. + appendix (mimeo-. Rep. to USDI, Bureau of Outdoor Rec., by Survey Res. Center, Univ. of Mich., Ann Arbor, Mich.

Interview survey of 1,303 U.S. families in 1971. Presents participation rates for a variety of outdoor activities (22 percent have camped). Participation in camping is shown to be strongly determined by level of household income and age of the household head. Camping participation by regions is: Northeast 15 percent, North Central 24 percent, South 16 percent, and West 36 percent. Use of public camping facilities was reported by 68 percent of the families; private facilities were used by 27 percent. Seventeen percent of all families had camped in the past year, and less than half of those had camped on five or more occasions. Five percent of the campers would like to camp more often. Presents comparable information for several outdoor activities as well as analyses of recreation as a temporary escape, and places where young children play.

11. Mueller, Eva and G. Gurin.
1962. **Participation in Outdoor Recreation: Factors Affecting Demand Among American Adults.** Outdoor Rec. Re-

sources Rev. Comm. Study Rep. 20, Chap. 6, Camping, pp. 62-71. Washington, D.C.

Interview survey of 2,750 representative heads of households in the United States, conducted during the fall of 1959 and the spring of 1960, to determine participation rates in outdoor recreation activities. One in six American adults went camping in the year prior to the survey and another one in 11 expressed a desire to do so in the future. Wide differences were found in regional participation rates: 34 percent in the West compared with 9 to 13 percent in other regions camped during the previous year. Western campers also went on more camping trips during the year: 19 percent went on five or more trips as opposed to 6 to 9 percent in other regions. Presents information on camper characteristics, preferences for comfort versus "roughing-it" when camping, and recreational activities of campers.

12. National Advertising Company.
1970. **The 1969 Study of Vacation Camping.** 3M Nat. Advertising Co. 22 p. Argo, Ill.

Questionnaire survey of vacation campers in 1969. Sample size and source not reported. 1969 was the first year that 18 percent of the respondents had camped on their vacation. Forty-nine percent of the respondents vacationed that year at an area they had never visited before and 65 percent plan to vacation in an area next year that they have never visited. Seventy-three percent used a camper vehicle of some type while 27 percent used a tent. Public campgrounds were preferred by two-thirds of the campers.

13. National Advertising Company.
1970. **Impulse Travel; Changing Trends in Auto Vacation Travel.** 3M Nat. Advertising Co. 49 p. Argo, Ill.

Based on 1,200 questionnaires distributed to auto vacationers at 21 vacation spots throughout the United States in 1970. Seventeen percent of the sample were camping. Results are presented for the total sample without specific reference to campers. Fifty-three percent of the respondents were visiting an area or region that they had never visited before. In addition, 83 percent indicated they were going to vacation in an area or region next year that they had not been to before. Most information related to the degree of divergence, and reasons for divergence from a planned vacation itinerary.

14. National Advertising Company.
1971. **The 1971 Study of Vacation Camping.** 3M Nat. Advertising Co. 38 p. Argo, Ill.

Questionnaire survey of 500 known camping families. Nearly one in three camping families preferred private campgrounds to state or national camping facilities. Eighty percent preferred their campground to be located at or near water. Over 50 percent moved to a new campground daily, while on a vacaion trip. The average family stayed at six to seven campgrounds on their last camping vacation trip. Five out of six respondents indicated they had taken camping vacations in the spring and fall; and one in two had done so in the winter. The average family spent over 34 days camping in 1970. The average family spent $17.18 per day while camping. Nearly 80 percent were using a recreational vehicle. One in six camping families had, at one time, rented camping equipment.

15. National Family Opinion, Inc.
1971. **The Family Vacation Market.** 87 p. Survey conducted for Better Homes and Gardens, N.Y.

Questionnaire survey of 8,063 families of a 10,000 family panel in 1971. Two out of every three families take at least one vacation per year averaging 12 days, visiting nearly three states, provinces, or countries, and spending $404. No camping data reported. Presents a demographic profile and selected trip characteristics for vacationers to each state, Canada, and several foreign countries.

16. Olney, Robert C.
1971. **Psychographics of the Auto Traveler: How Changing Life Styles Affect Travel Patterns.** Nat. Advertising Co. 7 p. Argo, Ill.

Based on questionnaires distributed at 21 vacation spots in the United States in 1970, and at 33 vacation spots in 1971. In 1971, 21 percent of the vacationing families were camping as opposed to 17 percent in 1970. Presents composite profiles of vacationing families in 1970 and 1971, their patterns of travel, sources of information about places to visit, trip planning, and deviations from plans.

17. Outdoor Recreation Resources Review Comm.
1962. **The Quality of Outdoor Recreation: As Evidenced by User Satisfaction.** Outdoor Rec. Resources Rev. Comm. Study Rep. 5, 95 p. Washington, D.C.

Questionnaire survey conducted at 24 major outdoor recreation areas, among a random sample of 10,982 visitors. Camping was the major attraction at four of the areas, and was available at several others. Of the overnight accommodations used by groups staying in or near the area, 39.4 percent were tent campgrounds, and 7.8 percent were trailer campgrounds. Nearly nine out of 10 of the groups not using camping facilities were not interested in camping. Campers reported their highest satisfaction with camping facilities at those recreation areas where camping was the dominant activity. Camper satisfaction was lowest at areas where sightseeing was dominant. In total, one out of eight campers reported dissatisfaction with the activity, and the most common reason for dissatisfaction was overcrowding. At one area (Rocky Mountain National Park) almost half of the campers expressed dissatisfaction, and three fourths of these listed overcrowding as the reason.

18. Reid, Leslie M.
1963. **Outdoor Recreation Preferences: A Nationwide Study of User Desires.** Mich. State Univ. 288 p. Lansing, Mich.
See No. 17.

19. U.S. Bureau of Outdoor Recreation.
1967. **Outdoor Recreation Trends.** U.S. Dep. of Interior. 22 p., illus. Washington, D.C.

Survey conducted by the Bureau of the Census reports an estimated 97 million camping occasions in 1965 and predicted 1980 and 2000 increases of 78 percent and 238 percent respectively. Also reports an increase in camping participation during the period 1960 to 1965 of between 8 percent and 10 percent of the adult population.

20. U.S. Bureau of Outdoor Recreation.
1968. **The 1965 Survey of Outdoor Recreation Activities.** U.S. Dep. of Interior. 101 p. Wash., D.C.

Household interview survey of 7,194 persons 12 years of age and older in 1965. Provides a detailed description of participants in 25 outdoor recreation activities, including camping. During 1965, 10 percent of the population went camping, averaging 6.9 days. Two percent went camping in remote areas, averaging 4 days apiece. Presents data on percentage of campers by census regions and their average days of camping per camper. Describes campers in terms of socioeconomic variables. Twenty percent of the campers expressed dissatisfaction with the activity, of which 29 percent mentioned overcrowding of campgrounds. Five percent of noncampers indicated an interest in becoming campers.

21. U.S. Bureau of Outdoor Recreation.
1972. **The 1970 Survey of Outdoor Recreation Activities Preliminary Report.** U.S. Dep. of Interior. 105 p. Wash., D.C.

Mail questionnaire survey of 46,450 persons 9 years of age and older concerning their participation in 14 major outdoor recreation activities. Twenty-one percent of the population (20 percent of the 12 and over age group) camped in 1970, averaging 11 days per participant. Twenty-five percent of the total households had one or more campers. Presents socioeconomic and demographic data on campers and on participants in 13 other outdoor activities.

22. Waite, Thomas L.
1971. **Camping Explosion — Getting away from it all and getting back to nature?** 1971 Recreation and Camping Study. 68 p. + appendix. Marketing Information, Berkeley, Calif.

Questionnaire survey of 4,491 campers at state parks in 15 states, in 1971. Campers averaged 4-5 camping trips in 1971. Forty-one percent planned their current trips less than 2 weeks in advance. Approximately one out of five campers owns a boat. Six out of 10 used a campground directory; 30 percent are members of a camping club. Also presents a demographic profile of campers and describes their equipment ownership, purchasing intentions, ratings of camping facilities, activities engaged in, magazine and guidebook readership, and products used while camping.

# PART II. STATE-REGION-PROVINCE SURVEYS

23. Bannon, Joseph J. and Paula Warwick. 1973. **Survey of Private Campgrounds in Illinois.** 35 p. Univ. of Ill., Champaign, Ill.

    Questionnaire survey of 1,072 campers visiting 28 Illinois private campgrounds in 1972. Reports camper ages, distances traveled, lengths of campground visit, past visits, return visit intentions, preferences for reservations, reasons for camping, facilities desired, equipment used (tents, 22 percent), sources of information, number of nights camped in 1971 (14.3 percent did not camp), frequency of visits to private campgrounds, size of home town, and camper evaluations of fees.

24. Bond, R. S. and G. J. Ouellette. 1968. **Characteristics of Campers in Massachusetts.** Mass. Agric., Exp. Sta. Pub. 572. 23 p. Univ. of Mass., Amherst, Mass. (Not available.)

    Questionnaire survey of 2,749 visitors to 17 public and 13 private campgrounds throughout the state of Massachusetts in 1964. More than 33 percent of the campers in state-operated facilities remained for only one night. Only 10 percent stayed for one night at the average private facility. In public areas 72.5 percent of all campers were vacationing; 48.5 percent of the campers used tents and 51.5 percent used some sort of mobile equipment. On public campgrounds 85 percent owned their camping equipment, 8 percent rented and 7 percent borrowed it. Camping parties consisted of an average of 5.4 persons. Discusses willingness to pay, distance willing to travel and reasons for selecting a campground.

25. Buist, Leon J. 1973 **The Relationship Between Privately Owned and Public Campgrounds in the State of Michigan.** PhD. dissertation. 100 p. Univ. of Washington, Seattle, Wash.

    Results of a questionnaire mailed to 430 private campground owners and interviews with 1,243 camping parties in private and state-operated campgrounds in 1972. Fifty-one percent of the interviews were conducted at private campgrounds; 27 percent expressed a preference for private campgrounds; 48 percent learned of the campground they were visiting through friends. Presents additional information on camper origins, past camping experience, and comparative camper images of public and private campgrounds. Selected findings from this study appear in the article entitled: "A Camper is . . ." appearing in *Michigan Natural Resources*, Vol. 42, No. 3 (May-June 1973), pages 12-15.

26. Carruthers, John Arthur. 1966. **Campers of the Finger Lakes, Pocono, and Catskill Regions.** Unpub. Master's thesis. 140 p., (mimeo). Cornell Univ., Ithaca, N.Y.

    Questionnaire survey of 529 campers and interview survey of 521 campers at selected campgrounds in New York and Pennsylvania during 1965. Approximately 50 percent of all campers had less than 5 years of camping experience. The average numbers of nights camped (1964) was 14 for public campground visitors and 21 at private campgrounds. At public areas 57 percent owned tents versus 48 percent at private areas. Average daily expenditures per party were $12.69. Also reports, in detail, on camper willingness to pay different camping fees, camper motivations, enthusiasm for camping, equipment investments, and demographic characteristics. Compares findings by public and private campgrounds and by type of survey—questionnaire versus interview.

27. Clark, F. G. 1936. **Some Preferences of Forest Visitors.** J. For. 34(9) : 840-843.

    Questionnaire survey of 300 visitors to Forest Service Region I (Montana, North Dakota, and Northern Idaho) campgrounds, in 1935. Sixty-two percent of the campers used tents, 1.3 percent house trailers, and 17 percent auto-trailers. Presents percentages of campers who favor various types of developments and campground improvements. Also reports sizes of city of origin, occupations, and recreational activities of campers.

28. Cohee, Melville H. 1970. **Private Outdoor Recreation Businesses—Camping Enterprises.** Dep. Nat. Resour. Res. Rep. 60. 78 p. Madison, Wisc.

    Study of camping enterprises includes (pp. 55-67) interview survey of 141

camping parties at 65 commercial campgrounds in Wisconsin in 1968. Forty-seven percent of the camping parties were using a tent; 34 percent had made advance reservations; 12 per cent had been camping for only 1-2 years. Includes a detailed analysis of camper preferences based on a list of 26 campground features. See No. 29.

29. Cohee, Melville H.
1972. **Recreation Areas and Their Use: An Evaluation of Wisconsin's Public and Private Campgrounds, Swimming Beaches, Picnic Areas, and Boat Accesses.** Dep. Nat. Resour. Tech. Bull. 55. 48 p., illus. Madison, Wisc.
Interview survey of 141 camping parties at private campgrounds and 153 at public campgrounds in 1968 and 1970. Presents rankings of camper preference for 26 different campground features. The top 10 items ranked at both public and private facilities were: cleanliness, swimming, shade, wide spacing between sites, helpful manager, fishing, quietness, bath-showers, store, and good access. Report also evaluates the quality and use of Wisconsin campgrounds, picnic areas, beaches, and boat access areas. See No. 28.

30. Cox, Rex W., Stanley E. Foss, and Gerald L. Horner.
1968. **Outdoor Recreation in North Dakota.** Dep. of Agric. Econ. Bull. 475. 53 p. N.D. State Univ., Fargo, N.D.
Mail questionnaire survey of 2,950 North Dakota residents in 1966. Thirty percent had camped, for an average of 8 days, during 1965; 26.5 percent would like to camp more often, and 18.2 percent expect to camp more often in the future. Describes participants in camping and several other outdoor activities in terms of age, education, family income, and place of residence (farm, rural non-farm, and urban).

31. Cox, Rex W., J. E. Johnson, and L. K. Cook.
1969. **Survey of Resident and Non-Resident Tourist Groups.** N.D. Agr. Exp. Sta. Bull. No. 482. 35 pp. N.D. State Univ., Fargo, N.D.
Questionnaire survey of 504 North Dakota resident groups and 2,155 nonresident tourist groups, and interview survey of 899 residents and 5,055 residents passing eight highway survey points during the summer and fall of 1967. Approximately 5 percent of the residents and 13 percent of the non-residents were towing or driving camping rigs. Presents information on travel destinations, expected expenditures, miles traveled, expenditures on last trip, recreation activities, and socio-economic characteristics by residents and nonresidents.

32. Dahle, Thomas L.
1956. **Michigan State Park Users Survey.** Bureau of Business Res. Rep. 19. 16 p. Mich. State Univ., Lansing, Mich.
Personal interviews with 894 visitors to 31 state parks, and questionnaires filled out voluntarily by 3,800 park users at 57 state parks, in 1956. Twenty percent of the visitors surveyed were camping, for an average visit of 7 days. The average daily expenditure by camping families was $9.24.

33. Delphendahl, Johannes.
1964. **Outdoor Recreation in Maine—Some Observations (on the 1963 Park Questionnaire).** Maine State Park Comm. 52 p. (mimeo). Augusta, Me.
Interview survey of 3,168 campers using Maine State Parks and Acadia National Park during 1963. Presents camper distributions by state of origin, family income, and participation in recreational activities while camping, for each park surveyed.

34. Delphendahl, Johannes.
1965. **Outdoor Recreation in Maine—A Study of the Supply of and the Demand for Outdoor Recreation.** Dep. Agric. & Bus. Econ. 213 p. Univ. of Maine, Orono, Me.
Includes a brief description (pages 167-168) of campers at Maine State Parks, based on a 1964 interview survey of 756 campers. Approximately one-half of the campers spent between $5.00 and $10.00 per day for food while camping. Describes activities engaged in by campers, state of origin, and party size.

35. Dice, Eugene F.
1973. **In the Private Campground Industry ... A Study of Camper's Attitudes and Spending Patterns.** Coop. Ext. Serv. Bull. E-757. 10 p. Mich. State Univ. Lansing, Mich.
Interview survey of 1,004 camping families at 100 privately owned campgrounds in Michigan during 1972. Ten percent of the campers were camping for the first time in 1972; 50 percent of

the campers had purchased their present camping equipment within the last two years. More than half of the campers spent at least 30 days camping in 1972; 69 percent expressed a preference for private campgrounds rather than public developments. Also presents data on camping equipment investments, purchasing plans, expectations of future camping activity, methods of trip budgeting, and frequency of restaurant meals while camping.

36. Easley, Arnold Thomas Jr.
1968. **The Characteristics of Campers and Camping Groups at New Brunswick Provincial Parks.** Master's thesis. 83 p. Univ. of New Brunswick, Fredericton, N.B., Canada.

Questionnaire survey of 2,191 visitors to 16 New Brunswick Provincial Parks during the Summer of 1966. Reports socioeconomic characteristics of campers, average expenditures ($3.22 per person per day), average group size (4 persons), average visit length (3 days in the Province, 1 day at the campground), miles traveled, equipment used, and characteristics of those campers who return year after year.

37. Fine, I. V., and E. E. Werner.
1960. **Camping in State Parks and Forests in Wisconsin.** Wisc. Vacation-Rec. Papers 1(3). 12 p. Univ. of Wisc., Madison, Wisc.

Interview survey of 385 camping parties at 12 state parks in Wisconsin in 1959. Reports an average daily expenditure of $12.35 per family while camping. Fifty-eight percent were using tents, 29 percent camping trailers, and 9 percent tent trailers. Also reports campers' incomes, origins, party size, age distributions, occupations, activities, and suggested campground improvements.

38. Florida Department of Commerce.
1972. **Florida Tourist Study, 1971.** 14 p. Florida Dep. of Commerce, Tallahassee, Fla.

This study is based, in part, on information provided by visitors registering at Florida Welcome Stations. The report includes data on the origins and destinations of visitors, major highways used by travelers, average group size, accommodations planned (campgrounds 6 percent, trailer parks 8 percent), purpose of trip, and characteristics of the Florida tourist.

39. Florida Division of Recreation and Parks.
1971. **Outdoor Recreation in Florida: A Comprehensive Program for Meeting Florida's Outdoor Recreation Needs.** 349 p. State of Florida, Dep. of Nat. Resour., Tallahassee, Fla.

Includes results of a 1970 survey of over 3,000 residents and tourists, identifying socioeconomic characteristics of tent campers, trailer campers, and primitive campers. Also reports characteristics of participants in several other outdoor recreation activities.

40. Gardiner, Dale W.
1973. **The Camper in Connecticut Private Campgrounds.** Unpublished report. 46 p. Storrs Agric. Exp. Sta., Univ. Conn., Storrs, Conn.

Interview survey of 319 camping families visiting 13 private campgrounds in Connecticut during 1972. Reports camper's incomes, occupations, equipment used, camping frequencies, reasons for campground selection, attitudes toward pricing, and satisfaction with facilities. Average camping participation was 22 days per year; 33 percent used tent trailers, 31 percent travel trailers, and 10 percent used motor homes and truck campers.

41. Gorman, Lewis E., III.
1973. **Evaluation of the Potential for Future Growth of the Campground Market in Delaware.** Unpublished Master's thesis. 98 p. Univ. of Delaware, Newark, Del.

Telephone survey of 500 Delaware households in 1972. Twenty-nine percent had camped at some time in the past, of which 49 percent had camped at least once each year since 1969. Twenty-six percent of the campers had quit camping prior to 1969, and 23 percent had not camped at all since 1969. Among those who have never camped, 22 percent have considered it, and 12 percent plan to go within the next 5 years. One out of every two campers who began camping between 1966 and 1969 used a tent for their first trip: use of tents by campers beginning since 1969 has fallen to one out of three. Reports place of residence, income and occupations for campers and non-campers. Also reports campers reasons for not starting to camp sooner, reasons for not camping recently, and barriers to returning for inactive campers.

42. Guido, A. T. and T. J. Cieslinski.
1969. **Camping in New Jersey.** Monograph No. 1. 40 p. N.J. State Parks and Forests, Dep. of Conserv. and Econ. Develop., Trenton, N.J.

An analysis of over 32,000 camping permits from 15 New Jersey state parks and forests during fiscal year 1968. Fifty percent used tents, 20 percent tent-trailers, 16 percent travel trailers, 5 percent pick-up campers, and 3 percent stayed in lean-to's provided by the State. The average length of stay was 3.5 days and the average party size was 4.4 persons. Also reports camper origins by state and region.

43. Hempel, D. J.
1967. **Nonresident Vacation Travel in Connecticut, Summer 1966.** 105 p. Monograph Series in Bus. Adm. No. 1. Bureau of Bus. and Res. Services, Conn. Dev. Comm., Hartford, Conn.

Interview survey with 5,406 motorists and 1,653 plane, train, or bus passengers during the summer of 1966. Forty-eight percent of the highway travelers were vacationers; 3.5 percent of the vacationing motorists were camping. The average daily expenditure by all vacationers was $31.98 per car group. Reports expenditures for several classes of visitors and types of expenditures. Presents estimates of total economic impact of vacationers, their demographic descriptions, and comparisons with findings of a similar study conducted in 1956.

44. Hendee, J. C., W. R. Catton Jr., L. D. Marlow, and C. F. Brockman.
1968. **Wilderness Users in the Pacific Northwest—Their Characteristics, Values, and Management Preferences.** USDA Forest Serv. Res. Paper PNW-61. 92 p., illus. PNW. Forest & Range Exp. Sta. Portland, Ore.

Questionnaires were sent on a random sample basis, to visitors who deposited cards at the self-registration stations located within the Glacier Peak Wilderness in Washington and the Eagle Cap Wilderness and Three Sisters Wilderness in Oregon in 1965. Nearly 2,000 questionnaires were sent out with 71 percent being returned. Report presents a detailed picture of wilderness visitor characteristics, behavior, attitudes, and opinions regarding specific wilderness management policies and practices.

45. Hutchins, H. Clifton, and Edgar W. Trecker, Jr.
1961. **The State Park Visitor: A Report of the Wisconsin Park and Forest Travel Study.** Wisc. Conserv. Dep. Tech. Bull. 22. 82 p. Madison, Wisc.

Interview survey of 20,262 motorists in 31 state parks and forests during 1958. Seventeen percent of the visitors were camping. Average daily expenditure, per party, was $16.38 for all classes of users. Describes state park visitors in terms of income, distance traveled to park, size of parties, reason for visits, length of visits, and attitudes toward park-use fees.

46. Johnson, Aaron C., Jr., R. A. Christiansen and H. A. Johnson.
1970. **Vacationer Characteristics and Recreation Interests at 90 Wisconsin Resorts in 1967.** Res. Rep. 66. 17 p. College of Agric., Univ. of Wisconsin, Madison, Wisc.

Questionnaire survey of 843 groups visiting selected Wisconsin resorts in 1967. Compares the characteristics of three classes of vacationers, according to their primary recreation interests: fishing, swimming, and mixed (but not including an interest in fishing or swimming). A comparison of accommodations used indicates 5 percent of the fishing group, 13 percent of the swimming interest group, and 5 percent with mixed interests were camping. Also reports group origins and destinations, sources of information, travel distances, occupations, and vacation characteristics, by groups.

47. Kittle, J. R., Fred R. Taylor and Rex W. Cox.
1965. **A Pilot Study of Certain Aspects of Outdoor Recreation in North Dakota.** Dep. of Agric. Econ. Bull. 459. 39 p. N.D. State Univ., Fargo, N.D.

Questionnaire surveys of sample of visitors to 11 outdoor recreation areas in North Dakota administered by the federal, state and local governments, in 1963. Average daily expenditure of camper groups was $24.64. Seventy-three percent of the park visitors were participating in camping. Presents information on user evaluations of parks, activities enjoyed by visitors, frequency of visits, expected and actual visit lengths, return visit intentions, distances traveled, and socioeconomic and demographic descriptions of camp-

ers and noncampers responding to two separate surveys.

48. Kraai, Glen.
1972. **Camper Survey, Michigan State Parks, Summer 1971.** 15 p., (mimeo). School of Nat. Resour., Lansing, Mich.
Questionnaire survey of an unreported number of campers at 59 Michigan state parks during the Summer of 1971. Seven percent were camping for the first time, and 9 percent were in their first year of camping. Presents detailed information, by parks, of camper preferences, attitudes toward camping and toward different segments of the camping experience, problems encountered, and managerial suggestions. Also presents demographic data, by park regions and for the state as a whole; presents state-wide summary of campers' socioeconomic characteristics.

49. LaPage, W. F. and Stephen Foster.
1965. **The Privately-Owned Campgrounds of New Hampshire. N.H.** State Planning Proj. Study Rep. 7. 62 p., illus. Concord, N.H.
Questionnaire survey of 1,000 visitors to private campgrounds in New Hampshire during 1964. Presents information on camper origins, preferences, motivations, experience, occupations, and attitudes toward public and private campgrounds.

50. LaPage, W. F.
1967. **Successful Private Campgrounds: A Study of Factors that Influence the Length and Frequency of Camper Visits.** USDA Forest Serv. Res. Pap. NE-58. 22 p., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
Questionnaires distributed at New Hampshire's 108 commercial campgrounds in 1964. Findings based on 1,000 mailed responses. The length and frequency of camping visits varied with the type of equipment the camper used, with campground size (no. of campsites), age of development, dollar investment, and water attraction of the campground visited. Visit length and return visit intentions were strongly related to the incidence of past visits to the campground.

51. LaPage, W. F.
1968. **The Role of Fees in Campers' Decisions.** USDA Forest Serv. Res. Paper NE-118. 24 p., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
Based on interviews with a random sample of 712 New Hampshire state park visitors in 1967. The average total trip expense was $103 with an average of $20 per family spent on user fees. Daily camping expenditures averaged about $11 per family. The average number of camping trips was 4 per camping family involving 23 days during the year. The effect of several fee levels on camping activity is discussed.

52. LaPage, W. F.
1969. **Campground Marketing: The Heavy-Half Strategy.** USDA Forest Serv. Res. Note NE-93. 6 p. NE. Forest Exp. Sta., Upper Darby, Pa.
In a sample of New Hampshire state park campers in 1967, half of the sample accounted for three-fourths of the reported 16,500 camping days. The average annual camping expenditure for heavy-half campers was two and a half times greater than that for the light-half campers. The heavy camper averaged three times as many camping trips (six versus two) during the 1967 camping season. Of the heavy campers, 68 percent had invested over $500 in camping equipment versus 26 percent of the light campers. Strategies for focusing a promotional campaign on the heavy half of the camping market are given.

53. LaPage, W. F., and E. G. Fisher.
1971. **Geographical Variation in Camper Expenditures.** USDA Forest Serv. Res. Note NE-139. 8 p. NE. Forest Exp. Sta., Upper Darby, Pa.
Interview survey of 642 camping families at six state parks in New Hampshire during 1967. The average daily expenditure per family was $11.81. Compares total daily expenditures and proportionate expenditures for fees, food, gas and oil, equipment, and entertainment, by parks and by type of visit (transient versus total trip at one park).

54. LaPage, W. F., and Dale P. Ragain.
1972. **Campground Marketing—The Impulse Camper.** USDA Forest Serv. Res. Note NE-150. 4 p. NE. Forest Exp. Sta., Upper Darby, Pa.
Random sample interview survey of 699 New Hampshire state park campers in 1967, and 736 Maine coast campers in 1969. Forty-six percent of Maine coast campers and 21 percent of New Hampshire state park campers selected

their campground on an impulse decision (made within 24 hours of arrival at the campground). The average daily expenditure for impulse campers visiting New Hampshire state parks was $12.57 per family, while that for non-impulse campers was $10.34. Impulse campers averaged 18, 21, and 26 days of camping in 1965, 1966, and 1967; non-impulse campers in those same years averaged 17, 17, and 22 days. Among impulse campers 23 to 26 percent had been camping for 1 year or less; for non-impulse campers 16 percent (Maine) and 28 percent (New Hampshire) had been campers for 1 year or less.

55. Maine State Park and Recreation Commission.
1969. **Maine State Park Camper Survey.** 22 p., (mimeo). Augusta, Me.

Questionnaire survey of 921 visitors to Maine state park campgrounds in 1969. Compares camper characteristics with those of a similar survey conducted in 1959. Fifty-one percent used tents, 40 percent used trailers; 75 percent were from out of state. Median daily expenditure per party was between $10 and $20. Also presents information on campers' family incomes, camping experiences in Maine, future camping plans, and likes and dislikes about camping in Maine.

56. Maine State Park Commission.
1960. **Maine State Park Camper Use Survey.** 24 p. State House, Augusta, Me.

Questionnaire survey of 2,687 families visiting Maine State Park camping facilities during 1959. Seventy-seven percent used tents, 13 percent camped in trailers, and 88 percent of the campers were from out of state. The average daily expenditure per family was $19.80. Swimming was the most preferred state park recreational activity. Also presents information on average visit length, past camping experience in Maine, and future camping intentions.

57. Montville, Francis E.
1965. **Private Campgrounds in Maine: Part 2—General Characteristics of the Users of Private Campgrounds in Maine.** Coop. Ext. Serv., A.B.E. Ext. 123. 15 p. Orono, Me.

Questionnaire survey of 1,317 campers visiting private campgrounds throughout the state of Maine in 1964. Reports the origin of Maine campers, family size, age distribution of campers, income, trip characteristics, sources of tourist information, and activities participated in during the visit.

58. New Jersey Department of Conservation and Economic Development.
1968. **New Jersey State Park Visitor Use Survey 1966-1967.** 56 p. N.J. Dep. of Conserv. and Econ. Develop. Trenton, N.J.

Based on interviews conducted at nine New Jersey State Parks and Forests with 2,575 visitors in 1966 and 1967. Thirteen percent of the heads of households, or group leaders, inerviewed indicated "camping" as their purpose of visit. Data is presented in terms of all state park users.

59. Ohio Department of Natural Resources.
Undated. **Direct From the Park Visitor: As Reported in the State Park Travel & Use Survey.** Div. of Parks. 29 p .Ohio Dep. of Nat. Resour., Columbus, Ohio.

Questionnaire survey of approximately 10,000 visitors to Ohio state parks on three days in 1958. Eleven percent of the visits were for camping. Presents data for all visitors in terms of residence, frequency of visits, expenditures, and family income levels.

60. Pike, Ruth E.
1957. **We Came to Camp in Washington State Parks: Overnight Camping Survey 1956.** 44 p., (mimeo). State Parks & Rec. Comm. Olympia, Wash.

Questionnaire survey of 10,976 camping parties at 40 Washington state parks in 1956. Ninety percent camped in tents. Average estimated expenditure per party per day was $27.14. Sixteen percent were visiting a Washington State Park for the first time. Presents information on camper origins, travel plans, length of visits, and camper opinions about needed improvements.

61. Roenigk, W. P., and G. L. Cole.
1968. **A Profile of Delaware Campers.** Univ. of Del. Agric. Exp. Sta. Bull. 370. 14 p. Newark, Del.

Questionnaire survey of 953 camping families visiting 10 State park campgrounds in Delaware from Memorial Day to Labor Day in 1967. The average family had been campers for 11 to 12 years, were currently camping for 25

days per year, and spent $10.28 per day on their current trip of 8 days. Forty-three percent used tents, 32 percent used a travel trailer, 22 percent used a camping trailer, 11 percent used a pickup camper, and 8 percent used a station wagon. The average investment in camping equipment was $1,686 for seashore campers, and $994 for forest campers. Twenty-two percent belonged to a camping club. Also gives information on camper activities and attitudes toward facilities.

62. Stong, Hildreth L., and Keith E. Duke. 1972. **The Need for and Implementation of a Fee, Charge, and Reservation System for Washington State Parks.** 174 p. Stanford Res. Inst. Menlo Park, Calif.

Questionniare study of 3,430 Washington state park campers in 1972. Thirty-one percent were using tents and 69 percent recreational vehicles. More than half of the campers planned their weekend summer camping trips less than 1 week in advance of the trip. The average size of the camping group was 4 persons. Twenty percent had rented equipment in the past. The average daily expenditure per person was $5.97 in 1969 and $6.91 in 1972, for non-residents; the average for residents was $3.96 in 1969 and $4.58 in 1972. Contains information on camper experience with equipment rentals, preferences for reservation systems and fee levels at state parks, and reasons for camping. Includes a detailed analysis of the supply and demand for campsites through 1985.

63. Taylor, Charles E., and Douglas M. Knudson.
1972. **The Camper in Indiana State-Operated Campgrounds.** Purdue Univ. Agr. Exp. Sta. Res. Bull. 888. 11 p. Lafayette, Ind.

Interview survey of 327 campers visiting 10 State-operated campgrounds in Indiana during 1970. Reports origins of campers, distances traveled, sources of information, activities attracting the camper, reasons for visiting, satisfaction with the visit, and the effect of crowding on willingness to return. Twenty-two percent of the campers felt that campgrounds were overcrowded.

64. Taylor, Charles E., and Douglas M. Knudson.
1973. **Area Preferences of Midwestern Campers.** Jo. Leisure Res. 5(2):39-48.

Interview survey of 480 state park campers in eight midwestern States. The northern midwestern States (Michigan, Minnesota, and Wisconsin) were most attractive to campers. The corn belt States and Missouri attracted mostly local residents. Very few campers from outside of the midwest were encountered in the survey.

65. Thompson, J. M., Jr.
1961. **Estimating the Tourist and Recreation Business in Vermont.** Econ. Res. Series No. 5. 44 p. Vt. Develop. Dep., Montpelier, Vt.

Post-card questionnaire survey of 4,160 out-of-state visitors to Vermont tourist information booths in 1959. Sixteen percent of the tourists were camping; their average party size was 3.8 persons, and their average expenditure per person per night was $4.75 ($18.00 per party). Also presents information on state of origin, overnight accommodation, and expenditures for northern and southern Vermont.

66. Vermont Development Commission.
1959. **Habits and Expenditures of Summer Vacationists in Vermont, 1958.** Econ. Res. Series No. 3. 21 p. Vermont Develop. Comm., Montpelier, Vt.

Questionnaire survey of 2,874 persons visiting 27 tourist information booths in Vermont during 1958. Survey identifies tourists' reasons for visiting Vermont, type of accommodations used (5.9 percent camped), length of stay, total expenditures and home addresses.

# PART III. LOCAL SURVEYS

67. Alden, Howard R.
1965. **Characteristics and Preferences of Recreationists in Selected Northern Idaho State Parks.** Univ. of Idaho Coll., For. Sta. Note 1. 2 p. Moscow, Idaho.

Interviews with 404 camping families in 1964, at three Idaho state parks. Average family size varied among the three parks from 3.3 to 4.2 persons. The average length of visit varied, between parks, from 5 days to 8 days. The average expenditure per person per day was $1.57, 82 percent of which was spent in the "local area." From 75 percent to 88 percent of the users (by park) came from outside the state of Idaho; and 89 percent had previously visited the state or came at the recommendation of friends and relatives. Reports very high levels of dissatisfaction with park sanitary facilities (38 percent), signs and information (26 percent), and concessions (56 percent).

68. Anonymous.
1972. **Economic Impact of Campgrounds—Spruce Woods and Grand Valley.** Manitoba Dep. of Tourism, Rec. and Cultural Affairs, Res. and Planning Br. 18 p. (mimeo). Winnipeg, Manitoba, Can.

Questionnaire survey of 782 campers at two campgrounds in Spruce Woods Provincial Park (Manitoba) in 1971. Eight percent were using truck campers, 37 percent tent trailers, 16 percent travel trailers, and 27 percent tents. Most frequent length of stay was one night. The average expenditure per party per night was $6.11 at one campground, and $11.29 at the other. Presents a breakdown of camper expenditures and derives a measure of local economic impact for each campground. Also presents information on travel patterns and visitor familiarity with KOA campgrounds.

69. Beardsley, W. G., and D. P. Duncan.
1965. **A Study of Private Campgrounds in Minnesota.** Minn. For. Notes 160. 2 p. Univ. of Minn., St. Paul, Minn.

Interview survey of 44 campers at 15 private campgrounds in Minnesota during July, 1964. Compares campground owners' and visitors' rankings of the features which attract people to private campgrounds in preference to public ones. "Less crowding" was ranked first by both campers and owners.

70. Beardsley, W. G., and D. P. Duncan.
1965. **Camper Reactions to Fees and Charges in Minnesota State Parks.** Minn. For. Notes 161. 2 p. Univ. of Minn., St. Paul, Minn.

Interview survey of 200 campers at five Minnesota State parks during July, 1964. Most campers were willing to pay $4.00 for park entrance fees, and $2.00-$2.50 for a campsite. (Current fees were $2.00, park entrance and $1.50, camping.) Also presents campers' ideas on park financing and their opinions on fees for firewood and electricity.

71. Brown, T. L., and L. C. Merriam, Jr.
1970. **A Comparative Study of Twin Cities State and City Park Users with Emphasis on State Park Campers.** Minn. For. Res. Note 213. 4 p. Univ. of Minn., St. Paul, Minn.

Based on interviews with 306 state park campers and 143 city park day-users in Minnesota in 1968. Compares outdoor recreation behavior patterns, demographic variables, and reasons for park visitation among the five parks studied.

72. Brown, T. L., and L. C. Merriam, Jr.
1970. **The Twin Cities Camper and the State Park Environment.** Minn. For. Res. Note 215. 4 p. Univ. of Minn., St. Paul, Minn.

Interviews with 449 randomly selected users of three state parks and two city parks in 1968. Parks were selected from different geographic regions of the state and have different natural environments. State park campers were found to have a slightly higher naturalistic orientation and to place a higher value on natural areas than city park picnickers.

73. Bultena, Gordon L., and Marvin J. Taves.
1961. **Changing Wilderness Images and Forestry Policy.** J. For. 59(3): 167-171.

Interview survey of 45 vacationers entering the Quetico-Superior area in 1956, and 428 canoeists and campers in developed campgrounds in Quetico Provincial Park (Ontario) and the Superior National Forest (Minnesota) in 1958. Describes visitors' images of the wilderness area, and their expressed desires for a variety of improvements and

facilities in the area. Eighty-five percent of the visitors came from urban areas.

74. Burch, William R., Jr.
1966. **Wilderness—The Life Cycle and Forest Recreational Choice.** J. For. 64(9): 606-610.

Questionnaire survey of a systematic sample of 740 camper families visiting the Three Sisters Wilderness Area and adjacent campgrounds in Oregon. The sample included 254 camper families who only camped at developed campgrounds, 62 who only camped in the wilderness, and 424 who had had both types of camping experience during the preceding 5 years. Combination camping families represent the early stages of the family life cycle; easy-access-camping families represent middle and postretirement stages; and remote-camping families represent those just beginning their families and those in the contracting stages of the family life cycle.

75. Burch, William R., Jr., and Wiley D. Wenger, Jr.
1967. **The Social Characteristics of Participants in Three Styles of Family Camping.** USDA Forest Serv. Res. Paper PNW-48. 30 p., illus. PNW Forest & Range Exp. Sta., Portland, Ore.

Questionnaire survey of 740 camper families visiting developed campgrounds and wilderness areas in Oregon, in 1962. Thirty-four percent of the campers used only developed campgrounds, 57 percent camped in both developed and roadless camping areas and 8 percent camped only in roadless areas. Compares family characteristics and attitudes toward other recreationists, by each of the above camping styles.

76. Buxton, S. F., and J. Delphendahl.
1970. **Campers at Lily Bay State Park—Socioeconomic Characteristics and Economic Impact.** Univ. of Me. Agric. Exp. Sta. Bull. 687. 28 p. Orono, Me.

Interview survey of 145 camping parties visiting Lily Bay State Park (Maine) from May 15 to October 15, 1967. The average camper at Lily Bay State Park spent $3.10 per day in the surrounding area. The average size of camping parties was 3.6 persons. Fifty-one percent of the average total trip expenditures occurred in the park area, 19 percent in Maine but outside of the park area, and 28 percent outside the state. In the park area the three most important types of expenditures were groceries (42 percent), gasoline (14 percent) and recreation-related expenses (11 percent). Also discussed: occupation, level of income, educational level, and age of head of party, in relation to participation in outdoor recreation activities.

77. Canavan, James J.
1973. **Analysis of Site-fee Differentials in a Massachusetts Public Campground.** Unpub. Master's thesis, 102 p. Univ. Mass., Amherst.

A report of an experiment in which waterfront campsites at Wells State Park, Mass., were priced at $4 per night, and non-waterfront sites at $2, in 1972. Formerly, all sites had been priced at $3. Results indicate a significant shift in use away from waterfront sites. Includes a questionnaire survey of 490 campers to determine reasons for campsite selection and reactions to the new fees.

78. Cardenuto, J. R.
1964. **Five Campground Economic Survey-1964.** 7 p. (mimeo). Paper presented at the Campground Assoc. of Pa. Annual Workshop. Penn. State Univ. Ext. Serv., Univ. Park, Pa.

Questionnaire survey of 504 camping families at five commercial campgrounds in Pennsylvania in 1964. Presents information on size of party, length of visit, origin of visitors, expenditures, sources of information and reasons for selecting the campground. The average expenditure per party was $22.17 for an average visit of 2 days. Also presents expenditure breakdown by 7 categories of expenses.

79. Cardenuto, J. R.
1964. **Survey of Stony Mountain Campground Visitors.** 3 p., (mimeo). Penn. State Univ., Univ. Park, Pa.

Questionnaire survey of 111 camping families visiting Stony Mountain Campground (privately owned) in Pennsylvania during the summer of 1963. Average family expenditure in the local community per visit was $17.76. Average visit was 2 to 3 days. Also presents data on state of origin, size of party, and length of stay.

80. Cardenuto, J. R.
1965. **Camper Preference Survey 1965.** 5 p., (mimeo). Paper presented at the

Campground Owners Workshop. Penn. State Univ. Ext. Serv., Univ. Park, Pa.

Questionnaire survey of 78 camping families at two commercial campgrounds in Pennsylvania in 1965. Reports camper origins, population of home communities, type of shelter used, type of trip, repeat visitation patterns, and factors, influencing campground selection. Forty-two percent of the campers were using tents, and another 36 percent used tent trailers.

81. Church, Glen R.
1973. **Campground Impact Study.** 18 p. Rept. No. 127, Dept. of Tourism, Rec., and Cultural Affairs, Winnipeg, Manitoba.

Questionnaire survey of 989 campers visiting three Manitoba campgrounds in 1972. Reports origins, destinations, visit lengths, equipment (23 percent tents), expenditures, and camper evaluations of the parks. Average daily party expenses, outside the parks, ranged from $6.18 to $8.18. Computes economic impact and compares findings with a similar survey at two other campgrounds. (See also No. 68.)

82. Connors, James F.
1972. **A Market Structure Analysis of the Sebago-Long Lake Campground Cluster.** Unpub. Master's thesis. 127 p. Univ. of Maine, Orono, Me.

Interview survey of 26 campground managers in southwestern Maine during 1970 on the subject of business and marketing practices. Study includes interview survey of 9 percent of the campers visiting the 26 campgrounds during 2 weeks in August, 1970. Identifies major reasons for visiting the camping region, alternative campgrounds considered, and factors influencing campground selection.

83. Cordell, H. K., and C. K. Sykes.
1969. **User Preferences for Developed-Site Camping.** USDA Forest Serv. Res. Note SE-122. 6 p. SE Forest Exp. Sta., Asheville, N.C.

Questionnaire survey of 383 heads of households at one campground on the Cherokee National Forest in 1966-67. Fifty percent used tents, 22 percent used camping trailers, 12 percent travel trailers, and 7 percent truck campers. Camper preferences are listed for a variety of campground and campsite characteristics.

84. Cordell, H.K., and G. A. James.
1972. **Visitors' Preferences for Certain Physical Characteristics of Developed Campsites.** USDA Forest Serv. Res. Pap. SE-100. 21 p. SE Forest Exp. Sta., Asheville, N.C.

Study based on interviews, questionnaires, and observation of visitors to a campground on the Cherokee National Forest (Tennessee) from 1966 through 1970. Report presents socioeconomic characteristics of campers and their preferences for several campsite characteristics including: amount of shade, nearness to comfort station, drinking water, and lake shore, privacy, and campsite drainage.

85. Davis, Robert Kenneth.
1963. **The Value of Outdoor Recreation: An Economic Study of the Maine Woods.** Unpub. PhD thesis. 152 p. Harvard Univ., Cambridge, Mass.

Interview survey of 121 users (including campers) of three areas of public and private land in northern Maine during the period May to November, 1961. Presents a detailed analysis of the users' willingness to pay for their recreational experiences. Also presents data on patterns of recreational use during the sampling period and descriptive data on users' incomes, occupations, ages, driving distances, and origins.

86. Etzkorn, K. Peter.
1964. **Leisure and Camping: The Social Meaning of a Form of Public Recreation.** Sociol. and Soc. Res. 49: 76-89.

Questionnaire survey of 64 campers at a California public campground, in 1962. The mean size of camping parties was 4.6 persons. The majority of campers came from either semirural or suburban residential environments. Five percent were on their first camping trip. Suggests a variety of hypotheses for examining the role of camping as different forms of leisure expression.

87. Gilbert, Alphonse Henry.
1963. **A Survey of Vacation Camping in Iron County, Michigan.** Master's thesis. 180 p. Mich. State Univ., Lansing, Mich.

Based on interviews with 100 campers at seven city, county and National Forest campgrounds in 1959, in northern Michigan. The average camping family of five stayed 1 week, and spent $88.58 while camping. Campers averaged 3

years of experience and 4 weeks of camping per year. Forty-four percent were using tents; 8 percent borrowed, and 1 percent rented their camping equipment. Also presents data on camping families' incomes, ages, group sizes and composition, occupations, state of origin, and equipment and facility preferences.

88. Gray, D. E.
1961. **Identification of User-Groups in Forest Recreation and Determination of the Characteristics of Such Groups.** Unpub. PhD dissertation. 241 p. School of Public Admin., Univ. of Southern Calif., Los Angeles, Calif.

Questionnaire survey of 315 persons whose names were obtained from automobile registration records of vehicles passing a checkpoint at Mammoth Lakes, California, during a 1-week period in August 1960. Presents profile descriptions of all respondents; campers, fishermen, hikers, hunters, and nature students. Profiles include data on age, income, sex, marital status, occupation, education, social class, property ownership, recreational interests, activities, and average length of visit. Seventy-six percent of the fishermen, 92 percent of the hikers, 93 percent of the hunters, and 80 percent of the nature students listed camping as one of their outdoor recreational interests. Of the campers, 82 percent were interested in fishing, 83 percent in hiking, 14 percent in hunting, and 23 percent in nature study.

89. Ground, Alice E.
1971. **Camper Characteristics and Activity Patterns in Two California State Park Campgrounds.** Abstract of a thesis from San Jose State College. 2 p. (mimeo). San Jose, Calif.

Interview survey of 120 campers at two state parks in California during 1970. Findings revealed that the unique park environment did not have a great influence on duration of camper stay; time available to the camping parties was the factor determining length of stay.

90. Hendee, J. C.
1967. **Recreation Clientele—The Attributes of Recreationists Preferring Different Management Agencies, Car Campgrounds, or Wilderness in the Pacific Northwest.** Dissertation Abstrs. 28(5). 2 p. Univ. of Wash., Seattle, Wash.

Mail questionnaire survey of 2,500 campers registered at 30 campgrounds and five back-country (wilderness) areas on two national forests and two national parks in the Pacific Northwest. Responses suggest that intensive campground development preferences and high equipment preferences go together. There was support by all campers for separate areas for tents away from trailers, more nature trails, more opportunity to talk to rangers, and for wide campsite spacing. Close to 50 percent of all the users were strongly opposed to charging fees on federal areas.

91. Hendee, John C., Richard P Gale, and William R. Catton, Jr.
1971. **A Typology of Outdoor Recreation Activity Preferences.** J. Environ. Ed. 3(1) : 28-34.

Questionnaire survey of 2,401 visitors to developed campgrounds and wilderness areas of western Washington, in 1966. Classifies campers into five types based on their preferred activities while on a camping trip, and examines the effects of age and education on interrelationships among the five types.

92. Jansen, E. F., Jr., C. T. K. Ching, G. E. Frick, and C. W. Chandler.
1971. **Economic Effects of Pawtuckaway State Park: II. Park User Characteristics.** N.H. Agric. Exp. Sta. Res. Rep. 17. 19 p. Durham, N.H.

Interview survey of 230 camper groups and 1,075 day user groups at Pawtuckaway State Park (N.H.) during the period 1966 to 1969. Reports average daily expenditures, in the park and surrounding area, by years and by type of use (day users and campers). Average daily expenditures, per capita, of campers ranged from $0.78 to $1.09. Comparable expenditures for day-users ranged from $0.25 to $0.43. Also reports place of residence, distance traveled to the park, and length of visit.

93. Johnson, Marc A.
1971. **The Regionality of the Maine Coast Camper and Its Effect on Campground Advertising.** Unpublished Master's thesis. 82 p. Univ. of N.H., Durham, N.H.

Interview survey of 831 campers visiting all campgrounds in coastal Maine during the summer of 1969. Describes campers' perceptions of coastal regions, their sources of information, trip plan-

ning processes, and trip characteristics, for each of four coastal attractions.

94. King, David A.
1965. **Characteristics of Family Campers Using the Huron-Manistee National Forests.** USDA Forest Serv. Res. Pap. LS 19. 11 p., illus. LS. Forest Exp. Sta., St. Paul, Minn.
Interview survey of 395 campers visiting the Huron and Manistee National Forests (Michigan) during the summer of 1962. About 80 percent of the campers took only one trip to the forests during the season, and their camping trips averaged 5 days in length. About half of the families had 10 years or more of camping experience, and about 7 percent were in their first year of camping. Fifty-six percent used tents as the major form of shelter with 30 percent using a travel trailer, 11 percent using a tent trailer, and only 1 percent had a pickup camper as their major form of shelter. Also presents information on incomes, occupations, education, family size, and place of residence, for visitors to each forest.

95. King, David A.
1965. **Some Socioeconomic Comparisons of Huron and Manistee National Forest Family Campers with Market Populations.** Pap. Mich. Acad. of Sci., Arts, and Letters (1964 Meeting) Vol. L: 49-65.
See No. 91.

96. King, David A.
1966. **Activity Patterns of Campers.** USDA Forest Serv. Res. Note NC-18. 3 p. NC. Forest Exp. Sta. St. Paul, Minn.
Sixteen hundred campers surveyed in 1962, on the Huron-Manistee National Forests. The percent of campers participating in 11 outdoor activities is given, as well as the amount of time spent on each activity during the camping visit.

97. King, David A.
1968. **Socioeconomic Variables Related to Campsite Use.** Forest Sci. 14(1): 45-54.
See No. 94.

98. LaPage, W. F.
1963. **The 1961 Bear Brook State Park Camper Survey—A Sampling of Camper Activities and Attitudes.** Unpub. rep. in files of NE. Forest Exp. Sta. 43 p., (mimeo). Durham, N.H.
Questionnaire survey of 312 camping parties visiting Bear Brook State Park (New Hampshire) during 1961. Fourteen percent were in their first year of camping; 75 percent used tents, 10 percent camping trailers, and 12 percent travel trailers. Measures the degree of camper satisfaction and relates it to visit length. Also presents data on camper origins, motivations, activities, return visit plans, and opinions about campsite quality.

99. LaPage, W. F.
1967. **Camper Characteristics Differ at Public and Commercial Campgrounds in New England.** USDA Forest Serv. Res. Note NE-59. 8 p. NE. Forest Exp. Sta., Upper Darby, Pa.
Data from 866 campers interviewed at four large commercial campgrounds and at four large state park and national forest campgrounds in New England in 1964 and 1965. Significant differences between 445 visitors to commercial campgrounds and 421 visitors to public campgrounds were found in campers' investment in camping equipment, camping mobility, methods of campground and campsite selection, camping interests and past experience, and frequencies of membership in camping organizations.

100. Lime, D. W., and C. T. Cushwa.
1969. **Wildlife Esthetics & Auto Campers in the Superior National Forest.** USDA Forest Serv. Res. Pap. NC-32. 8 p. NC. Forest Exp. Sta., St. Paul, Minn.
Interview survey of 248 auto campers at 31 campgrounds in the Superior National Forest, Minnesota, during 1968. The average length of stay was 7.2 days, 89 percent of the parties had been in the area before, and 65 percent had previously camped in the Superior National Forest. Fishing was the major attraction, and only 8 percent listed wildlife as a prime factor drawing them to the area.

101. Lime, D. W.
1971. **Factors Influencing Campground Use in the Superior National Forest of Minnesota.** USDA Forest Serv. Res. Paper NC-60. 18 p., illus. NC Forest Exp. Sta., St. Paul, Minn.
Interview survey of 248 campers visiting 34 campgrounds in the Superior National Forest Minnesota, during August of 1967 and August of 1968. Sixty-five percent of the campers had

camped in the Superior National Forest before, and 48 percent of all parties had previously visited the campground in which they were interviewed. Eighty percent of all campers had selected their campground destination before leaving home. Describes camper preferences for several campsite characteristics: waterfront, shade, size of campground and nearness to fishing opportunities.

102. Lime, D. W.
1972. **Behavioral Research in Outdoor Recreation Management: An Example of How Visitors Select Campgrounds in:** Environment and the Social Sciences: 198-296. Am. Psychol. Assoc., N.Y.

A review of several camper surveys and a report of an interview survey of 248 campers at 31 campgrounds in the Superior National Forest, Minnesota, during 1968. The purpose of the interviews was to determine reasons for campground selection. The most prominent reasons for picking a campground (in order of importance) were: (a) fishing opportunity, (b) "wilderness" atmosphere, (c) remoteness, (d) sites having view of lake or stream and well screened from neighbors, and (e) small size of campgrounds. Also reports sources of camper information about the campgrounds visited. See No. 100.

103. Lucas, Robert C.
1964. **Recreational Use of the Quetico-Superior Area.** USDA Forest Serv. Res. Pap. LS-8. 50 p., illus. LS. Forest Exp. Sta., St. Paul, Minn.

Interview survey of 292 visitors to the Boundary Waters Canoe Area (Minnesota), in 1961. About 41 percent of the wilderness area visitors did not stay overnight. The average length of visit was 1.75 days. Gives estimates of total area use and maps zones of light, moderate, and heavy use, by canoeists, motor canoeists, auto campers, boat campers, resort visitors, cabin campers, and day-users. Also presents data on trends in use, and visitor characteristics.

104. Lucas. Robert C.
1964. **The Recreational Capacity of the Quetico-Superior Area.** USDA Forest Serv. Res. Pap. LS-15. 34 p. illus. LS. Forest Exp. Sta., St. Paul, Minn.

Interview survey of 292 visitor groups to the Quetico-Superior Area, Minnesota, during the summers of 1960 and 1961. Thirty-three percent of the sample made up of campers at developed campgrounds, 8 percent were boat campers and 29 percent canoeists. Wilderness qualities were the main attraction for canoe trippers; other visitors considered fishing or scenery primary. Canoeists saw the wilderness as smaller than other visitors. Canoeists also felt the wilderness was overcrowded at lower levels of use, and objected strongly to motor boats. Logging was seldom noticed and not always objectionable.

105. Lucas, Robert C.
1964. **Wilderness Perception and Use: The Example of the Boundary Waters Canoe Area.** Nat. Res. J. 3 (3): 394-411.

Interview survey, conducted in 1960 and 1961, among a random sample of 278 camper groups visiting the Boundary Waters Canoe Area, Minnesota, including canoeists, auto campers, boat campers, resort guests, and private cabin users. Describes how each class of visitor perceives the "wilderness" and its role in attracting them to the area.

196. Lucas, Robert C.
1970. **User Evaluation of Campgrounds on Two Michigan National Forests.** USDA Forest Serv. Res. Pap. NC-44. 15 p., illus. NC. Forest Exp. Sta., St. Paul, Minn.

Based on 597 interviews with campers at 22 campgrounds on the Huron and Manistee National Forests in 1962. Resource quality ratings made earlier as part of a nationwide Forest Service recreation resource inventory did not agree with visitors' ratings and had little relation to use variations. Overall resource quality ratings by visitors were most associated with their judgment of general environmental quality (essentially scenery).

107. McCool, Stephen F., and Lawrence C. Merriam, Jr.
1971. **Camper-Outfitter Interaction and the Boundary Waters Canoe Area, Superior National Forest, Minn.** Minn. Forest Res. Notes 225. 4 p. Univ. of Minn., St. Paul, Minn.

Based on 499 interviews with canoeists returning from overnight trips into the Boundary Waters Canoe Area. Provides information on outfitter use, outfitter-

camper interaction, previous wilderness experience, travel method, Boundary Water Canoe Area knowledge and interest, and attitudes toward Boundary Water Canoe Area management issues.

108. McCoy, E. W., and J. R. Box.
1971. **Factors Affecting Visitation to Lake Martin Outdoor Recreation Sites.** Agric. Exp. Sta. Circular No. 184. 22 p. Auburn Univ., Auburn, Ala.

Interview survey of 56 parties of non-campers and 112 camping parties at two water-based outdoor recreation sites in east-central Alabama. Swimming, picnicking, and water skiing were the preferred activities of non-campers; for campers, the preferred activities were swimming, fishing, and boating. Market areas, in terms of visitor distances traveled, are delineated for each of the study sites.

109. McCurdy, D. R., and R. M. Mischon.
1965. **A Look at the Private Campground User.** USDA Forest Serv. Res. Paper CS-18. 12 p. CS. Forest Exp. Sta., Columbus, Ohio.

A questionnaire survey of 666 users of 12 private forest campgrounds in the Ohio Valley. Half of the campers had been going camping for less than 2 years. Seventy-five percent of the campers were on weekend trips, 39 percent of the campers used a travel trailer, 35 percent a tent and 16 percent a camping trailer, with the remainder using a camper truck, a bus, or a station wagon. Half the groups learned about the campground they were visiting from a friend. Classifies campgrounds on the basis of dominant use—transient, weekend, and overflow—and describes the users of each type.

110. Masse, R. F., and P. W. Fletcher.
1972. **Visitor Preferences and Characteristics: A Study of Campers in Northcentral Pennsylvania.** Abstract. 4 p. (mimeo). Penn. Agric. Exp. Sta. The Penn. State Univ. School of Forestry, Univ. Park, Penn.

Interview and questionnaire study of 597 camping parties at three public parks and three private campgrounds in 1971. Forty percent expressed no preference for either public or private campgrounds. Past experience at a public campground and a concern for costs were associated with preferences for public campgrounds. Past experience at a private campground, and a large financial commitment to camping (in terms of equipment ownership) were associated with a preference for private developments.

111. Merriam, L. C., Jr., and R. B. Ammons.
1967. **The Wilderness User in Three Montana Areas.** 54 p. School of Forestry, Univ. of Minn., St. Paul, Minn.

Interview survey of 108 campers visiting three wilderness areas in Montana. Includes a sub-survey, for comparison, of 49 campers at developed campgrounds in Glacier National Park. The length of stay averaged 8 days for the Bob Marshall Wilderness Area, 2 days for the Mission Mountains Primitive Area, and 4 days for Glacier National Park back-country areas. Presents information on ages, incomes, occupations, wilderness familiarity, and the meaning of wilderness, by each of the areas studied.

112. Milliken, J. Gordon, and H. E. Mew, Jr.
1969. **Recreational Impact of Reclamation Reservoirs.** 18 p., illus. U.S. Dep. of Interior, Bureau of Reclamation. U.S. Govt. Printing Office, Wash., D.C.

Based on personal interviews and mailed questionnaires from a sample of visitors (mostly campers) to three Bureau of Reclamation reservoirs in Colorado in 1968. The average daily expenditure ranged from $1.16 to $3.05 per visitor-day. The mean group boating investment ranged from $297.14 to $1,586.38, at the three recreation areas. Economic impact of the visitors on the local economy is discussed.

113. Moeller, George H., Rodney G. Larson, and Douglas A. Morrison.
1973. **Recreation User Management Opinions and Attitudes: The Case of the Allegheny National Forest of Pennsylvania.** USDA Forest Serv. 28 p., (mimeo). NE. Forest Exp. Sta., Upper Darby, Pa.

Based on personal interviews of 136 campers at four developed campgrounds and 281 boaters at five boat-launch sites located on the Allegheny Reservoir in 1970 and 1971. The average camper had 6 years of camping experience and stayed an average of 5 days. Approximately one third of the campers used tents; 16 percent were first-year campers; 52 percent had previously visited the reservoir. Presents comparative information on boaters and campers in terms of their age, in-

come, occupation, equipment, experience, group composition, activities, and opinions on resource management.

114. Moss, W. T.
1966. **Forest Recreation: A Profile.** 8 p. Georgia Forest Res. Council, Macon, Ga.
Interview survey of 217 camping families at several state, private, and federal (USFS) campgrounds in Georgia during 1963. Single families made up 56 percent of the groups, 26 percent were several families, 13 percent were families with friends and 4 percent were groups of friends. The average length of stay was 10 days. Expenditures per day were slightly higher while traveling than while camping, but only 19 percent reported that they spent more than $10.00 per day enroute. Presents data on campers' incomes, occupations, residences, travel habits, reasons for camping, and activities enjoyed while camping.

115. Munson, K. F., and H. J. Schweitzer.
1964. **Camp-Centered Recreation—A Study of Family Camping at the Pounds Hollow and Lake Glendale Recreation Areas.** 13 p. Coop. Ext. Serv., Univ. of Ill. Urbana, Ill.
Interview survey of 158 camping families at two campgrounds on the Shawnee National Forest, Illinois, during the summer of 1963. Presents information on length of stay, miles traveled, destination, and origin. Also describes campers in terms of party composition, age and occupation of head of household, years of camping experience, and type of camping equipment used (66 percent used tents). Includes data on facility preferences, activities enjoyed, camper satisfaction, and factors influencing selection of a campground.

116. National Advertising Company.
1970. **1970 Greater Nags Head Chamber of Commerce Visitors Study.** 47 p. Nat. Adv. Co., Argo, Ill.
Personal interview survey of 505 visitors to five tourist locations in the area of North Carolina's Outer Banks, in 1970. Twenty percent of the visitors were camping. Campers spent an average of $16.20 per day per party: $2.74 for lodging, $6.30 for food, $3.92 for recreation, and $3.24 for fuel. Presents information on visit frequencies, sources of information about the area, places visited, miles traveled, size of party, type of accommodations used, and general impressions of the area.

117. National Advertising Company.
1970. **1970 Lancaster County Visitors Study.** 41 p. Nat. Adv. Co., Argo, Ill.
Interview survey of 625 visitors to three tourist locations in the Pennsylvania Dutch area of Lancaster County, Pennsylvania, in 1970. Twelve percent of the visitors were camping. Average number of days away from home for the total sample was 4.9. Average total trip expenditure for campers was $115.20: lodging $21.30, food $42.40, recreation $33.70, and miscellaneous expenditures $17.80. Also reports visitor origins, tourist attractions visited, visit frequencies, sources of information, and visitor likes and dislikes about the area.

118. Nixon, H. N.
1967. **Banff National Park: Aspects of Visitor Use.** Nat. Parks Serv. Planning Rep. 26. 49 p. Dep. of Indian Affairs and Northern Develop. Ottawa, Ont., Canada.
Observational study of the number of visitors, residences, and types of camping equipment, at six campgrounds in Banff National Park in 1965. Also includes results of an observational study of shelter use at these same six campgrounds, and a study of picnic area use in the park.

119. Nixon, H. N.
1967. **Elk Island National Park Visitor Use Survey, 1967.** Nat. Parks Serv. Planning Rep. 35. 38 p. Dep. of Indian Affairs and Northern Develop. Ottawa, Ont., Canada.
Interview survey of 193 exiting visitors to Elk Island National Park, Alberta, in 1967. Reports origins of park traffic, visitor residences, party sizes, lengths of trip, trip destinations, sites visited, and activities engaged in.

120. Nixon, H. N.
1967. **Jasper National Park Visitor Use Survey 1966.** Can. Nat. Parks Serv. Planning Rep. 31. 213 p. Dep. of Indian Affairs and Northern Develop., Ottawa, Ont., Canada.
Questionnaire survey of 1,559 campers at eight campgrounds within Jasper National Park, Canada, during 1966. The average camper in Jasper Park in 1966 spent a total of approximately $15.10 per day for himself and his

party. The average party stayed in the campgrounds for 2.8 nights with a total expenditure per party per stay of about $42.25. Also reports camper origins, camping equipment in use (40 percent used tents), years of camping experience (average 7.5), occupation of head of household, and travel patterns of campers. This report also includes the results of two separate surveys of 228 nature trail users and 65 wilderness area users within the national park.

121. Nixon, H. N.
1968. **Prince Albert National Park Visitor Use Survey, 1967.** Nat. Parks Serv. Planning Rep. 34. 137 p. Dep. of Indian Affairs and Northern Develop. Ottawa, Ont., Canada.

An interview survey of 316 exiting visitors to Prince Albert National Park, Saskatchewan, in 1967. Presents data on distances traveled, trip lengths, visit lengths, camping equipment (tents, 40 percent), party size, sites visited, activities, and expenditures ($2.35 per camper-day). Also includes a survey of 575 back-country campers.

122. Nixon, H. N.
1968. **Riding Mountain National Park Visitor Use Survey, 1967.** Nat. Parks Serv. Planning Rep. 37. 54 p. Dep. of Indian Affairs and Northern Develop. Ottawa, Ont., Canada.

Interview survey of existing visitors to Riding Mountain National Park, Manitoba, in 1967. Presents data on distances traveled, trip lengths, visit lengths, camping equipment (28 percent used tents), party sizes, sites visited, activities and expenditures ($7 per camper party per day). Also includes results of a survey of visitors to Mt. Agassiz, a popular winter sport site near the park's eastern boundary.

123. Recreation Research and Marketing Information.
1971. **The Berkeley Camps: 1971 Opinion Survey of Berkeley Residents.** 83 p. + appendix. Rec. Res. and Marketing Information, Berkeley, Calif.

Questionnaire survey of 990 Berkeley, California, households in 1971. Fifty-one percent had camped within the past 12 months; 16 percent had last camped 2 to 5 years ago. Only 14 percent had never camped. Forty-one percent used a tent on their last camping trip; 12 percent used a camping vehicle, and 22 percent used only a sleeping bag. Also presents information on cost of last camping trip (59 percent spent less than $5), destination and activities on last trip, awareness of city-operated campgrounds and camper demographics.

124. Shafer, Elwood L., Jr.
1965. **Socioeconomic Characteristics of Adirondack Campers.** J. For. 63: 690-694.

Questionnaire survey of 561 heads of households from New York State who camped at four campgrounds in the Adirondack preserve in 1961. Each of the four campgrounds had a different resident-zone pattern, but the income distribution of campers was the same. Results suggest that camping areas in the Adirondacks may have individual characteristics affecting use patterns.

125. Shafer, Elwood L., Jr.
1969. **The Average Camper Who Doesn't Exist.** USDA Forest Serv. Res. Pap. NE-142. 27 p., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Based on a 1964 interview survey of 1,140 campers at 5 New York State campgrounds. Considerable variation found in camper characteristics at all five parks and within any one park from month to month: from 12 to 36 percent of the campers were on their first camping trip; from $49 to $70 was the average amount spent per party during their visit; and from 28 percent to 82 percent of the camping parties preferred a campsite beside a lake. Some similarities between parks are also noted. Tents were used by 63 percent of all campers, 21 percent had travel trailers, and 16 percent had camping trailers. Ownership of higher priced equipment was significantly related to years of past camping experience.

126. Shafer, Elwood L., Jr., and Hubert D. Burke.
1965. **Preferences for Outdoor Recreation Facilities in Four State Parks.** J. For. 63: 512-518, illus.

Personal interview survey of 800 visitors to four state parks in Pennsylvania in 1962. Visitors were asked to examine black-and-white photographs of different facilities and designate their preferences, after considering the cost per day they would have to pay. Measures direction and amount of demand for outdoor recreation facilities

in four northeastern Pennsylvania state parks. On both weekdays and weekends, campers differed significantly from noncampers in their preference patterns for swimming areas, fireplaces, camping facilities, and site spacing.

127. Siderelis, C. D.
1972. **The Effect of Travel Resistance and Trip Length on the Spatial Movement of Motor Campers From Four Origin Zones to Albuquerque, New Mexico.** Abstract of an unpub. paper from the files of the Dep. of Health, Physical Ed., and Rec. 3 p. Univ. of N.M., Albuquerque, N.M.

Questionnaire survey of 159 campers visiting five commercial campgrounds in the Albuquerque, New Mexico, area in 1971. Estimates the effect of enroute stimuli on the travel patterns of campers visiting Albuquerque and passing through 11 resistance zones from four points of origin.

128. Sinden, John A., and Lynn B. Sinden.
1964. **A Forest Recreation Survey: Implications for Future Development.** Scottish For. 18(2) : 120-127.

Interview and questionnaire survey of 203 campers in Snowdonia National Forest Park, North Wales, in 1963. Fifteen percent were camping for the first time. Campers with reported camping experience in 1962 averaged 20 days of camping in that year. Presents information on distances traveled, length of visit, activities enjoyed, preference for facilities, and needs for more campsites.

129. Stille, Thomas A.
1970. **Consumer Characteristics, Satisfactions, Preferences and the Demand for Camping at Davis Creek Park.** Abstract of a thesis. 3 p., (mimeo). San Jose State College, San Jose, Calif.

Questionnaire survey of 502 campers at a county park in California. Average family income was found to be significantly higher than the national, state, or local averages. Describes camper reactions to fees, satisfaction with facilities, group size, length of visit, and preferences for new camping developments.

130. Taves, M., W. Hathaway, and G. Bultena.
1960. **Canoe Country Vacationers.** Univ. of Minn. Agric. Exp. Sta. Misc. Rep. 39. 28 p., illus. St. Paul, Minn.

Interviews and subsequent mailed questionnaires of a sample of 383 visitors to the Quetico-Superior area of northeastern Minnesota. Both canoe campers and campers at developed campgrounds were surveyed. Presents data on campers' demographic characteristics, trip planning, visit satisfaction, and attitudes toward management, facilities, and other campers. Also contrasts a composite description of canoe campers with campground campers.

131. Taylor, G. D., and R. Y. Edwards.
1960. **A Survey of Summer Visitors to Wells Gray Park, British Columbia.** For. Chron. 36(4) : 346-354.

Questionnaire survey of 353 camping parties entering Wells Gray Provincial Park, Canada, in July and August of 1959. Average length of stay was 4 days. Seven percent were camping for the first year; 65 percent had camped 5 years or more. Also presents data on reasons for the visit, activities engaged in during the visit, residence, and occupation.

132. Wagar, J. Alan.
1963. **Relationships Between Visitor Characteristics and Recreation Activities on Two National Forest Areas.** USDA Forest Serv. Res. Paper NE-7. 19 p. NE. Forest Exp. Sta., Upper Darby, Pa.

Questionnaire survey of a systematically selected sample of 558 visitors to two recreation areas on national forests in West Virginia and Pennsylvania in 1960. Fifteen percent of the visitors were camping in the national forests. Reports a positive relationship between incidence of camping and distance from home, family income, and professional employment.

133. Wang, Darsan.
1971. **Camper Preferences and Campsite Characteristics at Ludington State Park, Michigan,** 137 p. MS thesis. Dept. of Park and Recreation Resources, Mich. State Univ., East Lansing.

Interview survey of 200 campers at three campgrounds in Ludington State Park, Mich., during 1970. Reports how campers select sites, satisfaction with sites, equipment, and size and composition of parties. Equipment included 83 tents, 69 tent trailers, 49 travel trailers, 11 pickups and 5 vans.

134. West, Richard F.
1965. **Preliminary Report on Results of Camping Study Made in Stokes and Bass River State Forests.** McIntire-Stennis Forestry Res. Program Project 256. 13 p., (mimeo). Rutgers Univ., Camden, N.J.

Interview survey of 55 camping parties visiting two New Jersey state forests in 1964. The average number of days camped per year was 19. Eighteen percent had been camping for 1 year or less; 56 percent had camped less than 5 years. The average daily expenditure per party was $12.30. Seventy-five percent used tents exclusively and another 18 percent used a tent in conjunction with a camping vehicle or trailer. The average investment in camping equipment was $345.00. Also presents attitudes and opinions about ideal campsites, activities while camping, camping motives, and demographic descriptions of campers.

135. Woerpel, Loren S.
1961. **Characteristics of the Family Camper in Northern Wisconsin and the Upper Peninsula of Michigan.** Wisc. Fed. of Conserv. Clubs. 21 p. + appendix. Stevens Point, Wisc.

Questionnaire survey of 386 campers at several county, state, and national forest campgrounds in Northern Wisconsin and the Upper Peninsula of Michigan, in 1960. Of the sample 7.5 percent had begun camping in 1960. Most of the analysis is based on the 357 families who began camping before 1960. Seventy-five percent of the families started camping with tents; 9 percent began with trailers, and the remainder used some combination of sleeping bags with an automobile and small tent. Thirty-two percent had changed their camping equipment since they started to camp; mostly from tents to trailers. Twenty-five percent go on one annual camping trip; another 38 percent take 2 to 3 trips per year. Also presents information on camper occupations, campsite preferences, and camping motivations.

# PART IV. MAGAZINE READERSHIP AND CAMPING ASSOCIATION MEMBERSHIP SURVEYS

136. Better Camping Magazine.
1963. **Profile of an Opportunity,** 34 p. Kalmbach Publishing Company, Milwaukee.

Questionnaire survey of 4,720 readers of Better Camping magazine in May and June, 1963. Presents a profile of camper and trip characteristics, activities, equipment owned, and purchase plans.

137. Better Camping Magazine.
n.d. **New Directions in the Camping Market,** 9 p. Woodall Publishing Company, Highland Park, Ill.

Reports the characteristics of Better Camping magazine subscribers, their incomes, ages, occupations, education, family size, camping experience, camping frequency, and recreational equipment ownership. (Sample size not reported.)

138. Better Homes and Gardens.
n.d. **Better Homes and Gardens Travel Questionnaire Study . . . A Report on Family Travel,** 116 p. Meredith Pub. Co., Des Moines, Iowa.

Questionnaire survey about the travel habits of more than 215,000 subscribers to the magazine in February and March of 1966. Includes sections on vacation planning, domestic travel, foreign travel, family camping, accommodations, credit card usage, car rentals, etc. Forty-one percent had taken a family camping vacation at some time in the past; 10 percent own campers, trailers, or pick-up units; and 29 percent would rent or have rented camping equipment. Thirty-six percent plan to take a family camping vacation soon.

139. Better Homes and Gardens.
n.d. **Better Homes and Gardens Study of Vacation Travel.** 58 p. Meredith Pub. Co., Des Moines, Iowa.

Questionnaires mailed to 2,000 respondents to an article appearing in the April, 1969 *Better Homes and Gardens* offering a free Travelaide Map and Directory. The 2,000 were selected randomly from the first 3,500 respondents to the article. The first 1,000 questionnaires returned formed the basis for the report. Twenty-two percent reported the use of camping equipment on their vacations.

140. Consumer Communications Corporation.
1969. **A Survey of Camping/Trailering Activities in Four Magazine Subscriber Groups and a Recreation Vehicle Owner Group.** 91 p., (mimeo). For Woodall Pub. Co. by Consumer Commun. Corp., Chicago, Ill.

Questionnaire survey of 3,341 persons who subscribed to four camping magazines, and 782 registered owners of recreation (camping) vehicles. Twelve percent had been camping for less than 1 year. Thirty percent plan their camping trips only a few weeks in advance. Presents descriptions, by sub-sample (magazine listing), of campers in terms of: family size, age, income, education, region of the country where residing, magazine readership, club affiliations, intentions to purchase a variety of leisure equipment, frequency and type of equipment rentals, and campgrounds visited recently (by ownership).

141. Consumer Communications Corporation.
1973. **Woodall's Keys to the RV Market, 1973.** For Woodall Pub. Co., by Consumer Commun. Corp., Chicago, Ill.

Questionnaire survey of 1,153 recreational vehicle owners in 1973. Compares findings to 1969 survey (see No. 140). Reports characteristics of owners, purchasing plans (38 percent plan to buy "new" units in next year or two), types of units planning to buy, and history of past vehicle ownership. Thirty-seven percent still owned their first recreational vehicle, 38 percent were on their second unit, 16 percent on third, and 9 percent on their fourth. A description of buying intentions indicates that existing RV owners plan to switch from camping and travel trailers toward motor homes, with the expectation that motor home purchases will represent more than 40 percent of all RV purchases by the end of 1976.

142. Davis Publications.
1973. **A Study of the Camping Journal Reader: 1,500,000 People . . . A 450 Million Dollar Market.** 24 tables. Davis Publications, Inc., New York, N.Y.

Questionnaire survey of 400 Camping Journal subscribers, conducted in May to July, 1972. Presents a profile of adult subscribers in terms of their camping activities, vehicle ownership, equipment ownership, magazine readership, age, education, income, and family size. Respondents averaged eight trips and 23 days of camping during 1971; 83 percent used recreational vehicles, and 45 percent used tents. Also reports sources of information used in planning camping trips, amount spent on camping and outdoor recreation in the previous 12 months, vehicle and recreational equipment ownership, year of purchase and method of purchase.

143. Driscoll, L. S.
1967. **Family Camping in Alabama.** Auburn Univ. Agric. Exp. Sta. Bull. No. 374. 30 p. Auburn, Ala.

Mailed questionnaire survey of 543 members of the Alabama Campers-Association and Alabama Members of the National Campers and Hikers Association in 1966. Thirty-two percent of the campers had been camping for 3 years or less; 25 percent used tents. The average weekend camping expense, per party, was $19.41 for two nights away from home. The average vacation camping trip of 11 nights cost $183.23. Also reports campers' willingness to pay different campsite fees, sources of campground information, distances traveled, equipment purchasing plans, activities, evaluations of campgrounds, and socioeconomic characteristics.

144. Gift, Robert F.
1964. **Factors Which Might Affect the Establishment of Standardized Campgrounds.** Master's thesis. 78 p. Dep. of Forest Manage., Penn. State Univ., Univ. Park, Pa.

Questionnaire survey of 134 members of the Nimrod Campers Club, in 1964. Thirteen percent had been camping for one year or less; and 73 percent had camped for less than 5 years. Seventy percent preferred to camp at public campgrounds, rather than at private ones. Presents demographic descriptions of campers, and their preferences for facilities, campground designs, fee levels, and travel patterns.

145. Green, B. L. and H. A. Wadsworth.
1966. **Campers: What Affects Participation and What Do They Want?** Purdue Univ. Agric. Exp. Sta. Res. Bull. 823. 23 p. Lafayette, Ind.

Questionnaire survey of 577 members of the Campers Association of Indiana, in December of 1963 and January of 1964. Average annual camping participation was 30 days, ranging from 19 days for tenters to 37 days for users of camping trailers. Twenty percent plan their annual camping vacation less than 1 month in advance. Also reports recreation activities desired by campers; fee levels that campers are willing to pay; magazine readership; and socioeconomic characteristics of campers.

146. Kerr, Glenn, and Martha Kerr.
1972. **3,959 Campers Polled on Parks.** Campground & RV Park Manage., 3(6): 1, 10-11.

Questionnaire survey of 3,959 National Campers and Hikers Association members in 1972. Type of equipment: 3 percent van, 5 percent motor home, 6 percent tent, 19 percent tent-trailer, 57 percent trailer and 9 percent truck camper. Presents findings of attitudes and opinions about a wide variety of campground management practices, including facilities, site spacing, level of development, fee levels, and measures to control use.

147. Kilpatrick, J. W., Jr.
1972. **The Role of the Consumer in the Lightweight Camping Market.** 9 p., (mimeo). For Better Camping Magazine. Woodall Pub., Highland Park, Ill.

A questionnaire survey of a random sample of 5,000 subscribers to Better Camping; 1567 questionnaires were returned; 39 percent indicated that they were already, or would become, lightweight campers in the near future. The campers make, on the average, seven hiking and six backpacking trips a year; 59 percent of all trips are of 1 to 3 days' duration; 3 percent last longer than 2 weeks. Includes information on shopping habits, equipment ownership, information sources, and demographics.

148. LaPage, W. F., and D. P. Ragain.
1972. **NAFCA Leadership Survey.** 7 p., (mimeo). Unpub. rep. in files of NE. Forest Exp. Sta., Durham, N.H.

Questionnaire survey of 182 Chapter Leaders of the North American Family Camping Association in 1971. The aver-

age number of years of camping experience was 11; years in the organization averaged 5. The campers averaged 13 camping trips visiting 13 campgrounds per year. Average number of nights spent camping was 46 in 1970 and 53 in 1971. Participation was increasing for 41 percent and decreasing for 19 percent between these two years.

149. McMullen, Katie.
1967. **Better Camping Sketches Camper Profile.** Family Camping Leader 5(2): 7-8.
Questionnaire survey of readers of Better Camping Magazine. Fifty percent use tents (down 20 percent from a similar survey in 1963); 25 percent camp at private campgrounds. Average years of camping experience, 4.5. Average annual participation was five weekend trips and one 2-week vacation trip. Sixty-three percent spent less than $200 on their annual vacation trip. Also reports desired facilities, activities, and family income, size of city of residence, home ownership, and head of household's occupation.

150. National Campers and Hikers Association.
1972. **NCHA Publishes Campsite Survey Results.** Family Camping Leader 9(7): 1-6. Family Camping Fed., Martinsville, Ind.
See No. 146.

151. New England Family Camping Association.
1961. **The Which? The What? The Who? of Campers' Likes and Dislikes: Results of NEFCA Survey.** Campfire Chatter Aug., 1961. NEFCA, Newburyport, Mass.
Questionnnaire survey in April, 1961 of the New England Family Campers Assoc. membership. Twenty percent responded; 41 percent used tents, 27 percent travel trailers, 20 percent tent trailers, 10 percent station wagon and tent, and 1 percent pick-up campers. Reports an average of 4 weeks of camping per year; 14 percent had camped for one year only. Includes data on camper preferences for a variety of recreational facilities and management practices.

152. Outdoor Life Magazine.
1966. **A Survey of Foods for Camping and Sporting Trips,** 22 p. (mimeo). Outdoor Life, New York, N.Y.
Questionnaire survey of a sample of 663 subscribers to Outdoor Life magazine in 1965. Thirty-eight percent reported having camped during the previous 12 months. Also reports number of trips, purpose of trips, trip lengths, and food consumption habits while on camping and sporting trips.

153. Outdoor Life Magazine.
1968. **Outdoor Life Camping and Trailer Unit Study Results—Report No. I.** 7 p. Outdoor Life, New York, N.Y.
Reports the findings from a mailed survey of 549 subscribers to Outdoor Life in 1967. More than 42 percent owned a camping or trailer unit. Reports types of units owned, number of trips taken in previous year, days spent camping, miles traveled, uses made of camping units, place of purchase, age of owner, household income, and number of persons in household.

154. Outdoor Life Magazine.
1970. **Outdoor Life Camping Survey.** 42 p. Outdoor Life, New York, N.Y.
Reports findings of a 1970 questionnaire survey of 622 Outdoor Life subscribers. Of the total respondents, 69 percent planned to camp in the next year, and 62 percent camped in the past year. Reports types of campgrounds visited, facilities desired, incidence of winter camping, camping trip characteristics, ownership of recreational vehicles, attitudes toward vehicle rentals, vacation home ownership, and socioeconomic characteristics of campers.

155. Sunset Magazine.
1971. **Vacation and Travel: A Sunset Magazine Reader Survey.** 6 p. Lane Magazine and Book Co., Menlo Park, Calif.
Questionnaire survey of the vacation and travel activities of 1,296 readers of Sunset Magazine, conducted in February, 1971. Presents a summary of answers to each of 16 questions. Topics included are number of vacation trips taken in 1970, when taken, plans for trips in 1971, length of planning period (less than 1 month for 12 percent, type of transportation, type of accommodations used on vacation (tents 15 percent, camping vehicles 21 percent), use of travel agent, median annual vacation expenditure ($598), age of wife and husband, education level of wife and husband, and total household income.

156. Woodall Publishing Company.
1970. **Keys to the Rec-Vee Camping Market USA, A Demographic and Motivational Study.** 38 p. Woodall Publishing Co., Highland Park, Ill.

Questionnaire survey of 1,237 subscribers to Woodall's Travel Trailer Magazine and 803 registered recreational vehicle owners, separately for each sample, in terms of socioeconomic characteristics, camping behavior patterns, club membership, buying behavior, and magazine readership. Fourteen percent of the licensed vehicle owners had camped for less than 1 year. Between one fourth and one third of all respondents planned their camping trip only a few weeks in advance.

# PART V. MISCELLANEOUS REPORTS OF SURVEYS AND OBSERVATIONAL STUDIES RELATED TO CAMPING

157. Audience Research, Inc.
1958. **Outdoor Recreational Activities and Preferences of the Population Living in the Region of the Delaware River Basin.** 75 p. National Park Serv. Study, Princeton, N.J.

Interview survey of 510 adults representing households in New Jersey and parts of Pennsylvania, Delaware, and New York, in 1957. Forty-seven percent had taken at least one overnight or weekend trip during the past 12 months; 2 percent of them were camping trips. Presents detailed information on recreational patterns and preferences of people taking day outings and overnight trips.

158. Bates, Scott, and William Harman.
1970. **Results of the 1970 Springfield College Campsite Preference Survey.** 10 p., (mimeo). Rec. Dep., Springfield College, Springfield, Mass.

Questionnaire survey of 1,125 people visiting the Springfield, Massachusetts, Camping and Outdoor Show in February, 1970. Visitors at the Springfield College exhibit were asked to fill out a questionnaire to determine campsite preferences. Results are compared with a similar survey conducted in 1965. Questions asked considered the following campsite preference factors: kind of equipment, degree of shade, distance between sites, size of campground, screening, cooking fuel, distance to water, distance to comfort stations, distance to refuse receptacles, open fireplace, laundry facilities, flush toilets, shower facilities, electricity, and swimming. In 1965, 47 percent used tents; by 1970 tenters were down to 30 percent. Use of propane fuels and the need for electricity at campsites increased significantly. Preference for other facilities showed little or no difference between 1965 and 1970. See also No. 185.

159. Beardsley, Wendell.
1967. **Cost Implications of Camper and Campground Characteristics in Central Colorado.** USDA Forest Serv. Res. Note RM-86. 7 p., illus. RM. Forest & Range Exp. Sta., Ft. Collins, Colo.

Twenty-one campgrounds were selected at random from the Roosevelt, Pike, and Arapaho National Forests in Colorado. During the summer of 1965, the investigator visited the campgrounds each weekend, observing 1,062 camping groups, their equipment, choice of campsites, and state of residence. Fifty-eight percent of the campers were using a travel trailer, tent trailer or a pickup camper while 38 percent were using tents. About 10 percent of the single campground family units contained two or more families. Campers using travel trailers and tent trailers were observed adjacent to a surfaced highway. Sixty-three percent of the campers were from Colorado. Non-residents outnumbered residents by two to one at campgrounds adjacent to paved highways.

160. Bultena, Gordon L., and Lowell L. Klessig.
1969. **Satisfaction in Camping: A Conceptualization and Guide to Social Research.** J. Leisure Res. 1(4) : 348-354.

Presents selected findings from several camper surveys and suggests a conceptual approach for studying the components of camping that provide satisfaction: type of resource base, style of

camping, level of physical activity, pattern of social interaction, and the nature of derived values. Hypothesizes major camping motivations based upon existing survey findings.

161. Burch, William R., Jr.
1965. **The Play World of Camping: Research into the Social Meaning of Outdoor Recreation.** Amer. J. Sociol. 70(5): 604-612.
Interviews were conducted in 1962 with 288 families at 12 campgrounds in three National Forests in Oregon. Observations were recorded while author and family lived at campgrounds. Six identifiable types of play actions were observed. They were: 1. symbolic labor, 2. expressive play, 3. subsistence play, 4. unstructured play, 5. structured play, and 6. sociability. Play actions which are normative for women tend to be prosaic, while those assigned to men tend to be dramatic. When asked what they would like changed in the forest, men would emphasize play items such as fishing, better access roads and better boat-launching ramps while women emphasized comfort items such as better toilets and piped-in water.

162. Burch, William R., Jr.
1969. **The Social Circles of Leisure: Competing Explanations.** J. Leisure Res. 1(2): 125-147.
This paper, using data from a 1962 camper survey in Oregon, examines three possible explanations for differences in camping styles: the compensatory hypothesis, in which individuals will seek to do the opposite of their regular routine; the familiarity hypothesis, which assumes that once a comfortable routine has become established it will be carried over into one's leisure; and the personal community hypothesis, which suggests that one's social circles will influence not only attitudes toward social issues but leisure behavior patterns as well. In examining all three hypotheses, data are drawn from a sample of 254 auto campers, 62 wilderness campers, and 424 campers who engaged in both wilderness and auto-access camping. See No. 161.

163. Burch, William R., Jr.
1970. **Recreation Preferences as Culturally Determined Phenomena.** In B. L. Driver (ed.) Elements of Outdoor Recreation Planning: pp. 61-87. Univ. Microfilms, Ann Arbor, Mich.
A philosophical treatment of the influences of culture and technology on the perception and use of free time. Includes a brief report of the author's original research on the relationships between occupational status and style of camping participation. Three camping styles are considered: easy access, remote, and those who participate in both types. Easy access campers were found to be under-represented at the upper professional levels and over-represented among the professions with lower occupational status.

164. Burdge, Rabel J.
1965. **Occupational Influences on The Use of Outdoor Recreation.** Unpub. PhD Dissertation. 178 p. Penn. State Univ. Dep. of Agric. Econ. and Rural Sociol. Univ. Park, Pa.
Interview survey of the leisure-time activities of 1,562 residents of Allegheny County (Pittsburgh), Pennsylvania in 1963. Compares occupational characteristics (prestige, income, hours, paid vacations) with outdoor recreation activity interests. Compares survey percentages engaged in different outdoor activities with those of Mueller and Gurin (1962). Only 5 percent of all respondents in the Pittsburgh Leisure Time Study reported participation in camping, with considerable variation by professions: Accountants 0 percent, Draftsmen 14 percent, Teachers 17 percent, Carpenters 0 percent, Cranemen 0 percent, Mechanics 9.5 percent, Janitors 3.4 percent, Plant Guards 13 percent, Nurses 10.5 percent.

165. Bury, R. L.
1964. **A Comparison of Visitors and Use at Three Campgrounds in Northern California During 1958 and 1961.** Forest Rec. Res. Project. 13 p., (mimeo). PSW Forest and Range Exp. Sta., Berkeley, Calif.
An analysis of campground fee receipts from three national forest campgrounds in Northern California from the years 1958 and 1961. Presents information on 1958 to 1961 trends for each campground, in terms of: total attendance, size of group, average visit length, day of arrival, and county of residence.

166. Bury, R. L.
1964. **Do Campers Fit Our Campgrounds?** Trends in Parks and Rec. 1(1): 15-16.
See No. 168.

167. Bury, R. L.
1964. **Information on Campground Use and Visitor Characteristics.** USDA Forest Serv. Res. Note PSW-43. 3 p. PSW. Forest & Range Exp. Sta., Berkeley, Calif.

Describes procedures for effective collection and use of campground registration data.

168. Bury, R. L., and Helen A. Barr.
1964. **A Survey of Campers' Equipment and Group Size: Summit Ranger District, Stanislaus National Forest 1961.** USDA Forest Serv. Rep. 12 p., (mimeo). PSW. Forest & Range Exp. Sta., Berkeley, Calif.

Observational study of campers visiting seven campgrounds on the Stanislaus National Forest, California, in 1961. One campsite in five was occupied by a group of two or more families. About 50 percent used tents, 20 percent camping trailers, 10 percent truck campers. About one-fifth of the camping groups slept in the open. Six percent put up two or more tents.

169. Bury, R. L., and Ruth Margolies.
1964. **A Method for Estimating Current Attendance on Sets of Campgrounds . . . a pilot study.** USDA Forest Serv. PSW. Res. Note PSW-42. 6 p. PSW. Forest & Range Exp. Sta., Berkeley, Calif.

Statistical models were devised for estimating both daily and seasonal attendance (and corresponding precision of estimates) through correlation-regression and ratio analyses. Total daily attendance for a test set of 23 campgrounds could be estimated from attendance measured in only one of them. The chances were that estimates would be within 10 percent of true attendance, two out of three times.

170. Campbell, F. L., J. C. Hendee, and Roger Clark.
1968. **Law and Order in Public Parks.** Parks and Rec., Dec. 1968, 3: 28-33 and 51-55.

Observational study of campers at three intensively developed campgrounds—one each in a National Forest, National Park, and State Park, in the State of Washington. Reports and analyzes incidents of theft, vandalism, destructive play, littering, rule violations, and illegal camping.

171. Catton, William R., Jr.
1969. **Motivations of Wilderness Users.** Reprinted from Pulp and Paper Magazine of Canada, Dec. 1969. 8 p.

See Nos. 44 and 170.

172. Catton, William R., Jr., and John C. Hendee.
1968. **Wilderness Users . . . What Do They Think?** Am. Forests 74(9) : 28-31, 60, & 61., illus.

See No. 44.

173. Clark, Roger N., John C. Hendee and Frederick L. Campbell.
1971. **Depreciative Behavior in Forest Campgrounds: An Exploratory Study.** USDA Forest Serv. Res. Note PNW-161. 12 p. PNW. Forest & Range Exp. Sta., Portland, Ore.

Based upon systematic participant observation and information collected from campground rangers at a national park, a national forest, and a state park in Washington, campers were found responsible for much depreciative behavior. Teenagers did not commit a disproportionate number of depreciative acts. Pre-teenage children in groups of two or three appeared to be the primary cause of much expensive damage to facilities. Factors associated with depreciative behavior such as vandalism, theft, littering, rule violation and nuisance behaviors are discussed along with possible methods of control.

174. Clark, R. N., J. C. Hendee, and F. L. Campbell.
1971. **Values, Behavior, and Conflict in Modern Camping Culture.** J. Leisure Res. 3(3) : 143-159.

Data collected during the summers of 1968 and 1969 by: (1) participant observation to become familiar with problem behavior patterns in modern campgrounds, (2) questionnaires submitted to campers in seven campgrounds in Washington state inquiring about their knowledge of and attitudes toward undesirable behavior in public campgrounds, and (3) questionnaires mailed to recreation managers in state parks, national parks, and national forests in Washington. Several differences were found in the camping attitudes and opinions of users and managers of highly developed campgrounds. Users and managers have different concepts of what constitutes an environmental experience, and they perceive behavioral problems differently. The users find conditions common to the urban environment such as noise, litter, even

vandalism and theft less disturbing than do managers. Several comparisons between campers' and managers' views are presented, on the subjects of rule enforcement, camping, values, crowding, and the extent of problem behavior.

175. Clarke, Michael George.
1964. **An Analysis of a Private Luxury Campground In Michigan's Ottawa National Forest.** Master's thesis. 131 p. Dep. of Forestry, School of Nat. Resources, Univ. of Mich., Ann Arbor, Mich.
A financial analysis of a new (1963) private luxury campground within the Ottawa National Forest, Michigan, and a comparison with a nearby rustic public campground. Includes an observational analysis of visitors to both campgrounds, in terms of types of camping equipment in use, lengths of visits, and use intensity.

176. Cole, G. L. and B. T. Wilkins.
1971. **The Camper.** Forest Rec. Symp., Oct. 12-14, pp. 105-112. Northeastern Forest Experiment Station, Upper Darby, Pa.
A partial summary of selected camper-survey findings. See Nos. 24, 26, 61, 71, 72, 75, 76, 106 and 125.

177. Donovan, George A.
1972. **Camping in Vermont, May to October, 1971.** 6 p., (mimeo). Econ. Res. Rep. 72-2. Agency of Develop. and Community Affairs, Montpelier, Vt.
Report of attendance statistics submitted by private campground operators and the Vermont Department of Forests and Parks for 1971. Includes data on camper nights, campground occupancy, out-of-state visitors, party size, length of visit, and expenditures. Camper trip expenditures averaged $5.00 per person per day; and the average party size was 3.9 persons.

178. Dyer, A. A., and R. S. Whaley.
Undated. **Predicting Use of Recreation Sites.** Utah Agric. Exp. Sta. Bull. 477. 21 p. Logan, Utah.
Analysis of camper origins (from license plates) of campers visiting the Logan Canyon camping complex in the Cache National Forest, Utah. Also includes an analysis of origins of fishermen visiting two streams in northern Utah based on interview data collected in 1966.

179. Elsner, Gary H.
1971. **Campground Users ... a computerized method for summarizing where they come from and how long they stay.** USDA Forest Serv. Res. Note PSW-258. 5 p. PSW. Forest & Range Exp. Sta., Berkeley, Calif.
Presents a computerized method for summarizing market area information from campground permits. Point-of-origin and length-of-stay of campground users can be estimated and summarized quickly and inexpensively. A test of the method for a campground on the Sierra National Forest, California, is also presented.

180. Ericson, Richard R.
1973. **An Analysis of Maine/Maritime Vacation Travel.** 77 p. Maine Dept. of Commerce and Industry, Augusta.
Questionnaire survey of 3,644 randomly selected persons crossing the Maine-New Brunswick border in the summer of 1972; plus an interview survey of 964 Maritime visitors. Campgrounds were the type of accommodation most frequently used in Maine by travelers going to and from the Maritimes, accounting for over one-third of all primary lodging choices.

181. Frick, G. E., and C. T. K. Ching.
1970. **Generation of Local Income from Users of a Rural Public Park.** J. Leisure Res. 2(4) : 260-263.
Analyzes income generated by park user expenditures at Pawtuckaway State Park, New Hampshire, during the period 1966 to 1969. See No. 92.

182. Gray, James R., and L. Wayne Anderson.
1964. **Recreation Economics in South-Central New Mexico.** Agric. Exp. Sta. Bull. 488. 20 p., illus. N.M. State Univ., Las Cruces, N.M.
Interview survey of 292 recreationists in or near the Ruidoso Ranger District of the Lincoln National Forest in 1962, including 155 campers and picnickers. The investment per party in recreation equipment averaged $700 for campers and picnickers. The average expense per party of campers and picnickers was $47.77 for automobile expenses, $5.78 for lodging, $21.38 for additional food (estimated cost of food over and above food cost at home), $2.45 for equipment rental, $1.06 for horse rental, $3.30 for license fees, $1.62 for other fees, $8.77 for other miscella-

neous and $19.88 for depreciation of equipment, for a total expense of $112.68, or an average per man-day of $6.62. Presents estimates of local economic impact from recreation.

183. Hancock, H. K.
1971. **A Comparison of Observed Camper Behavior With Verbal Expressions of Site Preference and Perception, in Cache National Forest, Utah.** Abstract of unpub. PhD dissertation. 153 p. Utah State Univ., Logan, Utah.

Interview survey of 279 camping parties visiting a campground on the Cache National Forest, Utah, in 1970. Compares characteristics of campsites with occupants' stated preferences for vegetative density around the site. Less densely vegetated sites were preferred by older campers with long histories of camping experience, and higher than average levels of formal education.

184. Hancock, H. K.
1973. **Recreation Preference: Its Relation to User Behavior.** J. For. 71(6): 336-337.

Interview survey of 280 camping parties visiting a campground in the Cache National Forest, Utah, in 1970. Compares characteristics of campsites with occupants' stated preferences for vegetative density around the site, using five experimentally treated campsites. Over five, two-week periods, the percentage of original vegetation at the campsites was drastically reduced. However, campers using the sites throughout the summer expressed approval of the current vegetative density.

185. Harrison, Gerald A.
n.d. **Results of the 1965 Springfield College Campsite Preference Survey.** 7 p. (mimeo). Springfield College, Springfield, Mass.

Questionnaire survey of 1,036 campers visiting the 1965 Springfield Camping and Outdoor Show. Reports camper preference for campsite spacing, shading, screening, and distances to various campground features. Forty-seven percent were tent campers. See No. 158.

186. Hendee, John C., and Frederick L. Campbell.
1969. **Social Aspects of Outdoor Recreation—The Developed Campground.** Trends in Parks and Rec. 6(4): 13-16.

Observation study of campers' recreation behavior in three highly developed campgrounds in Washington State. For many visitors to intensively developed campgrounds, the camping experience is social rather than environmental. Reports an increasing incidence of multiple-party camping groups; and a related need to provide several units in each campground where two families can camp together. Describes types of social behavior by campers and their implications for managers of developed campgrounds.

187. Henry, W. F.
1967. **The Visitors to Mt. Washington, Characteristics and Opinions.** 52 p. Univ. of N.H., Durham, N.H.

Interview survey of 251 auto tourists and cog railway riders (parties) plus a questionnaire survey of 90 guests at the Summit House, and 77 trail hikers, on Mt. Washington, New Hampshire, in 1966. Fourteen percent of the auto and railway visitors and 22 percent of the hikers were camping on the night before their visit. Does not include detailed descriptions of campers.

188. Hodgson, Ronald Wayne.
1971. **Campground Features Attractive to Michigan State Park Campers.** Master's thesis. 77 p. Mich. State Univ., E. Lansing, Mich.

A comparison of physical characteristics at Michigan State park campgrounds having longer and shorter than average lengths of visits. Campgrounds with long lengths of visits were more likely to have swimming facilities, a boat launching ramp, and tended to be less crowded and located on rolling terrain.

189. Hunt, John D.
1968. **Tourist Vacations—Planning and Patterns.** Utah Agric. Exp. Sta. Bull. 474. 40 p. Utah State Univ., Logan, Utah.

Interview survey of 343 tourist parties stopping at the Bear Lake Overlook (U.S. 89) in Utah, during the period June 15 to September 1, 1964 and 1965. Forty-six percent of the tourists had camped at least one night during their trip. Campers were more willing than noncampers to deviate from their planned route of travel for recreation, touring, sight-seeing, and eating or sleeping. Presents information on tourist trip planning, planning periods, sources of planning assistance, and trip scheduling.

190. Hunt, John D., and Perry J. Brown.
1969. **Expenditures of the 1968 Utah Summer Motor Vehicle Tourist.** 49 p., illus. Inst. for the Study of Outdoor Rec. and Tourism. Utah State Univ., Logan, Utah.

Data collected in June, July, and August of 1968 by means of travel diaries distributed at major entry points to the state of Utah three times during the summer to all nonresident travel parties during a 2-hour period. Twenty-six percent of the diaries were returned. Findings relate to all tourists with no summaries for campers. The average length of stay per party was 1.5 days. The average size of the party was 3.4 persons. The average expenditure per persons per day was $7.95. Expenditure by type of purchase was: food—28.5 percent, lodging—23.5 percent, transportation—31.5 percent, entertainment —3.5 percent, other retail purchases—12 percent, and services—1.0 percent.

191. James G. A., and H. K. Cordell.
1970. **Importance of Shading to Visitors Selecting a Campsite at Indian Boundary Campground in Tennessee.** USDA Forest Serv. Res. Note SE-130. 5 p. SE. Forest Exp. Sta., Asheville, N.C.

Interviews with 383 campers and questionnaire survey of 107 campers disclosed that most campers favored campsites with moderate to heavy shading, and 90 percent preferred sites which had a limited amount of vegetative screening between them and the adjacent campsites.

192. James, George A., Gordon R. Sanford, and Andrew Searcy, Jr.
1972. **Origin of Visitors to Developed Recreational Sites on National Forests.** J. Leisure Res. 4(2) : 108-118.

Postal zip codes and information on recreational use can be obtained easily by self-registration and other fee-collection methods from almost all visitors to Forest Service recreational sites where user fees are charged. Information on visitor origin and other data were collected during 1970 from visitors to many national forest campgrounds and day-use sites. This paper describes procedures for obtaining such information easily and inexpensively and presents examples of the types of computer outputs available.

193. Johnson, Aaron C., Jr., and Rudolph A. Christiansen.
1969. **Characteristics of the Wisconsin Resort Vacationer.** Coll. of Agric. and Life Sci. Res. Div. Res. Rep. 48. 10 p., illus. Univ. of Wisc., Madison, Wisc.

A survey of 843 user groups visiting privately operated vacation resorts in Wisconsin from June to October 1967. Eighty-three percent of the resort user groups planned to rent a cabin or cottage, 2 percent planned to use tents, 2 percent tent-trailers, 2 percent house trailers, and 1 percent truck campers; 52 percent listed fishing as their primary recreation activity; 85 percent were vacationing for 2 weeks or more.

194. Kampgrounds of America, Inc.
1973. **KOA News, Survey Data, Effects of Gasoline Situation on Camping.** 3 p. KOA, Inc., Billings, Montana.

Mailed questionnaire survey in August 1973 of 481 KOA system campers. The threat of a gas shortage forced 2 percent to abandon their 1973 camping plans; another 7 percent reported a "serious" effect on their plans; and another 30 percent were slightly affected by the gas shortage. Reports measures taken by campers to conserve energy, their camping activity in 1972 (average: 24 days), estimated activity for 1973 and 1974, plans for equipment change, and age, education, income, and occupation.

195. LaPage, W. F.
1968. **The Role of Customer Satisfaction in managing Commercial Campgrounds.** USDA Forest Serv. Res. Paper NE-105. 23 p., illus. NE. Forest Exp. Sta., Upper Darby, Pa.

Reports relationships between camper satisfaction and increased campground revenue at a New Hampshire State Park, and at several private campgrounds. Average visit lengths were increased by nearly 200 percent among highly satisfied campers. Return visit intentions were more than three times as common among satisfied, versus dissatisfied, campers. And average visit lengths at successful commercial campgrounds were over twice the length of those at less successful enterprises.

196. LaPage, W. F.
1969. **The Camper Views the Interview.** J. Leisure Res. 1(2) : 181-186, illus.

Reports camper reactions to having been interviewed while camping at New

Hampshire State Parks in 1967. Data collected by mail questionnaire approximately 2 months after the campground interviews. Also compares effectiveness of interviewers.

197. LaPage, W. F.
1970. **Campground and Camper Market Research.** Trends in Parks and Rec. 7(1) : 7-12.
Summarizes data from a variety of camper surveys and relates findings to stages of camping market growth and marketing strategies.

198. LaPage, W. F., and D. P. Ragain.
1971. **A Second Look at the Heavy Half of the Camping Market.** USDA Forest Serv. Res. Paper NE-196. 9 p. NE. Forest Exp. Sta., Upper Darby, Pa.
Questionnaire survey of a panel of more than 500 campers who supplied annual participation data over a 4 to 5 year period. Campers resided throughout the U.S. and Canada but were originally interviewed in 1964-65 at four public campgrounds and four private campgrounds in New England. By annually splitting the sample of 565 campers at the median number of days camped, it was determined that, in the first year, the heavy half accounted for 73 percent of the panel's total reported camping days and in the second, third, and fourth years the heavy half did more than 80 percent of all reported camping. Among consistently light campers, 57 percent had decreasing trends in camping participation, as opposed to only 6 percent of those campers who were consistently in the heavy half.

199. LaPage, W. F., and D. P. Ragain.
1971. **Trends in Camping Participation.** USDA Forest Serv. Res. Paper NE-183. 22 p., illus. NE. Forest Exp. Sta., Upper Darby, Pa.
Data based on a panel composed of 565 campers who annually reported their level of camping activity and any factors which might influence their camping participation. The panel averaged about 21 camping days per year. One-third of the panel members were found to have a decreasing participation trend after 4 years. Only 17 percent were increasing their camping frequencies. Commonly associated with a declining camping trend were: (1) a low past volume of camping, (2) an exploratory style of camping, and (3) a traditional or wilderness orientation to camping.

200. LaPage, W. F., and D. P. Ragain.
1973. **Family Camping Trends—An Eight Year Panel Study,** Unpub. report in the files of the NE. Forest Exp. Sta., Durham, N.H. 29 p., (mimeo).
A panel consisting of 459 camping families which had reported their camping activities from 1964 to 1971 revealed participation trends of: 25 percent increasing, 24 percent constant, and 51 percent decreasing. Twenty percent of the panel members were no longer active campers after 8 years. In 78 percent of the cases the incidence of one inactive year led to either further inactivity or a depressed level of camping activity. The most common complaint about the camping environment was of overcrowding, mentioned by 24 percent of the campers on the panel.

201. Lime, David W.
1972. **Large Groups In the Boundary Waters Canoe Area—Their Numbers, Characteristics, and Impact.** USDA Forest Serv. Res. Note NC-142. 4 p. NC. Forest Exp. Sta., St. Paul, Minn.
Interview survey of 1,352 visitors entering the Boundary Waters Canoe Area during the summer of 1971. Compares party size classes with several variables, including party composition, primary mode of travel, place of residence, length of stay, use of an outfitter, and depth of wilderness penetration.

202. Lime, David W.
1973. **Locating and Designing Developed Campgrounds to Provide a Full Range of Camping Opportunities.** USDA Forest Serv. 43 p., (mimeo). NC. Forest Exp. Sta., St. Paul, Minn.
A discussion of campground location and design principles drawing upon the findings of several camper surveys. The emphasis is on public ownerships and the need for a wide variety in the types of camping opportunities provided within a region. This paper also discusses the role of campground design in reducing resource deterioration and enhancing the camping experience.

203. Love, L. D.
1964. **Summer Recreational Use of Selected National Forest Campgrounds in the Central Rocky Mountains.** USDA Forest Serv. Res. Paper RM-5. 23 p.,

illus. RM. Forest & Range Exp. Sta., Ft. Collins, Colo.

Observational study of campers and day-users of 12 national forest campgrounds in Arizona, New Mexico, Colorado, Wyoming, and South Dakota, in 1962. The use of tents exceeded the use of travel trailers by a ratio of 1.5 to 1. Camper visits averaged 27.35 hours. Campsite use was influenced by distance from toilets, distance from drinking water, distance to next campsite, distance to fishing waters, and size of the clearing around the fire grate. Also reports origins and age groups of campers.

204. Lucas, R. C.
1963. **Visitor Reaction to Timber Harvesting in the Boundary Waters Canoe Area.** USDA Forest Serv. Res. Note LS-2. 3 p. LS. Forest Exp. Sta., St. Paul, Minn.

Interview survey of over 200 visitors to the Boundary Waters Canoe Area, Minnesota, in 1960 and 1961. Sample includes 96 campers at developed campgrounds and 85 canoeists. Presents findings on visitor reactions to logging. See No. 103.

205. Lucas, R. C.
1965. **The Importance of Fishing as an Attraction and Activity in the Quetico-Superior Area.** USDA Forest Serv. Res. Note LS-61. 3 p. LS. Forest Exp. Sta., St. Paul, Minn.

Interview survey of over 200 groups visiting the Boundary Waters Canoe Area, Minnesota, in 1960 and 1961. Sample includes 96 campers at developed campgrounds and 85 canoeists. Presents findings on the importance of fishing to each class of users. See Ref. No. 103.

206. Lucas, R. C.
1967. **The Changing Recreational Use of the Boundary Waters Canoe Area.** USDA Forest Serv. Res. Note NC-42. 4 p. NC. Forest Exp. Sta., St. Paul, Minn.

According to roadside interviews in 1961 and camper registrations in 1966, boat camping increased by 56 percent from 1961 to 1966. The average length of stay for boat campers decreased from 3.9 days in 1961 to 3.6 days in 1966. Auto campers' average visits also decreased, from 4.3 days to 3.8 days.

207. McArthur, J. Wayne, William R. Summitt, and Robert O. Coppedge.
1971. **Outdoor Recreation in North-Central New Mexico, 1967.** USDA Economic Res. Serv. ERS-483. 30 p., illus. Washington, D.C.

Questionnaire survey of 2,333 visitors to campgrounds, motels, and major tourist attractions in north-central New Mexico. Presents information on visitors' expenditures, distances traveled, party size, incomes, ages, occupations, and impressions of the adequacy of services. Does not include detailed descriptions of campers.

208. Maddock, Stephen J., G. A. Gehrken and W. A. Guthrie.
1965. **Rural Male Residents' Participation in Outdoor Recreation.** USDA Forest Serv. Res. Note SE-49. 2 p. SE. Forest Exp. Sta., Asheville, N.C.

Interview survey of a random sample of 200 male residents of Brunswick County, Virginia in 1964. Five percent had camped in the past year (1963), for an average of 12 days. Hunting and fishing were the most common outdoor recreation activities, involving 58 percent of the sample.

209. Marquardt, Raymond A., A. F. McGann, J. C. Ratliff, and J. C. Rouston.
1972. **The Cognitive Dissonance Model as a Predictor of Customer Satisfaction among Camper Owners.** J. Leisure Res. 4(4) : 275-283.

Telephone interview survey of known campers in three Wyoming cities—Casper, Cheyenne, and Laramie. Measures camper owners' post-purchase satisfaction and correlates it with length of ownership, cost, annual use of equipment (average: 39.6 days), and with age, income, and education of owners.

210. Merriam, L. C., Jr., A. S. Mills, C. E. Ramsey, P. C. West, T. L. Brown, and K. D. Wald.
1973. **The Camper in Minnesota State Parks and Forests: Some Insights on Use and Management From a Five-Year Study.** Univ. of Minn. Agric. Exp. Sta. Bull. 510, Forestry Series 12. 19 p., illus. St. Paul, Minn.

A summary and synthesis of several studies over a 5-year period (1967-1971) among visitors and managers of Minnesota state parks and forests and two city parks. Examines visitor preferences for different levels of park development, camper-manager communi-

cation, needs for nature interpretation, and visitor-administrator differences in preferences and perceptions.

211. Moeller, G. H., Robert MacLachlan, and D. A. Morrison.
1972. **Measuring Recreationist's Perception of Outdoor Recreation Environments.** 22 p., (mimeo). Unpub. rep. in the files of the NE. Forest Exp. Sta., Syracuse, N.Y.
Interview survey of 60 campers, 60 picnickers, and 60 hikers visiting selected recreation areas in Pennsylvania and New York state during 1969. Similarities and differences are reported among the three user groups in their perceptions of each other, and of the recreation environments in which they were interviewed.

212. New Brunswick Department of Tourism.
1973. **New Brunswick Private Campgrounds Occupancy Report: Year Summary—1972.** 10 p. Dep. of Tourism, Res. and Planning Br., Fredericton, New Brunswick, Canada.
There are approximately 130 privately operated campgrounds in New Brunswick, containing an estimated 5,600 campsites. Presents information gathered from a questionnaire survey of campground operators. Includes operator estimates of camper origins and length of visits.

213. Ontario Ministry of Natural Resources.
1973. **An Opinion Survey on the Use, Ownership, and Management of Natural Resources** (folder) Ministry of Nat. Res., Ontario.
Questionnaire survey of 1600 Ontario heads of households. Thirty-eight percent had camped during the past year, and 54 percent felt that the Ontario government currently provides adequate camping opportunities. Also presents data on resource ownership and use, and opinions about urban expansion, environmental quality, and resource use conflicts.

214. Ross, Terence L., and George H. Moeller.
1973. **Approaches to Communicating Rules in Recreation Areas.** 23 p. Unpub. manuscript in files of NE. Forest Exp. Sta., Syracuse, N.Y.
Questionnaire survey of 558 campers at two campgrounds on the Allegheny National Forest, Pennsylvania, in 1972. Surveys the extent of camper's knowledge about the rules and regulations of the campground which they were visiting. Campers who were uninformed about rules and regulations outnumbered those who were informed. Offers suggestions, based upon findings, for improving rule communication to campers.

215. Shafer, Elwood L., Jr., and John F. Hamilton, Jr.
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private land in Eastern Maine from January 1959 to November 1960. Eleven percent of the visitors were camping. Presents evaluations of the area's roads, facilities, and forest practices, by six user groups: ice fishermen, fishermen, campers, picnickers, vacationers, and hunters.

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Compares three methods of estimating use at 12 campgrounds in National Forests in Arizona, New Mexico, Colorado, Wyoming, and South Dakota.

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225. Wagar, J. Alan.
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226. Wagar, J. Alan.
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Within a large recreation area the attendance at several campgrounds may rise and fall in uniform response to such factors as weather, day of the week, vacation periods, insect activity, and fishing seasons. Where this common pattern exists, the number of campers at supervised campgrounds may be used to estimate attendance at unsupervised campgrounds in the park or forest.

227. Wallace, Oliver P., Sr., and David P. Olson.
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228. West. P. C., and L. C. Merriam, Jr.
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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

# Some Options for Managing Forest Land in the Central Appalachians




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WARREN T. DOOLITTLE, DIRECTOR

## FOREWORD

This paper reports the joint efforts of a multifunctional research team to assess the interactions of different management activities on four resources of the Appalachian forests.

The team was established and is conducting research so that management decisions on the forest lands may reflect various alternative management objectives, and so that better multiresource management may be practiced.

The field of multiresource management is controversial. One reason for this is that products such as visual appeal, water quality, and wildlife do not have tangible market values. Value determinations for them are rudimentary and imprecise so it is difficult to compare the consequences of various management decisions in a meaningful manner. Also, there is much less knowledge as to the effects of different management actions on wildlife and visual appeal than there is about timber and water responses to management.

Of necessity, this report is a tentative step in the direction of multiresource management and evaluation. In the future, we hope that many of the subjective evaluations presented in this report can be made much more precise. And finally, we are grateful for the many review comments and suggestions given us by our friends in universities, state agencies, and industries and by our colleagues in the Forest Service.

W. T. Doolittle
*Director*

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# Some Options for Managing Forest Land in the Central Appalachians


## ABSTRACT

For years foresters have recognized the principle of multiple use, and progress has been made toward managing forest resources to satisfy more than a single human need. But much more progress is needed if our forest land is to satisfy the many needs of a growing population with more free time and more money.

This publication is intended to broaden the forester's perspective in evaluating the suitability of tracts for a variety of uses and use mixes.

We made an attempt to evaluate for the area of the central Appalachians (which includes most of West Virginia and portions of the five adjacent states) the general effects of different forest practices on the following resources: timber, water, visual appeal, and wildlife. What is presented is a series of options from which choices can be made to meet particular owner objectives. With this information in hand, the manager should be in a better position, not only to fulfill his objectives, but to favor conditions beneficial to other uses with different objectives.

The management options presented apply to the forest ecosystems that predominate in the central Appalachian region. These are the basic forest land units we chose to use in comparing and evaluating the effects of the various practices on the four forest resources. The seven forest ecosystems, which are described in detail, are: (1) the oaks, (2) Appalachian mixed hardwoods, (3) northern hardwoods, (4) white pine, (5) Virginia pine, (6) red spruce, and (7) floodplain hardwoods. Each of these ecosystems, and quality of forest sites likely to occur within it, was rated as to its inherent capacity to supply each of the four resources.

Management for any forest product ordinarily involves tree cutting, so profitable tree harvest offers the most practical vehicle of management. Three broad management methods were considered for each ecosystem: even-aged management, uneven-aged management, and no commercial harvesting. The first two of these methods were subdivided into conventional cutting practices, and all were rated as to desirability to produce timber, water, visual appeal, and wildlife. The desirability ratings have no quantitative significance; they express a specialist's judgment of how each forest product is likely to be influenced by the specified practice.

Thus, the user of this paper is presented with a series of forest management options, from which he may choose those cutting practices best suited to his peculiar combination of forest resources and of land ownership objectives. Examples at the end of the paper show how options might be selected in actual forest management.

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## Introduction

FOR YEARS FORESTERS have recognized the principle of multiple use, and progress has been made toward managing forest resources to satisfy more than a single human need. But much more progress is needed if our forest land is to satisfy the many needs of a growing population with more money and more free time.

The type of forest ownership and size of property affect the degree to which multiple use can and will be practiced. On large public holdings, where great pressure exists for the fulfillment of a wide diversity of demands, there is no doubt that a real attempt will be made to meet the needs. And on any large forest area that is in one ownership, the practice of multiple use is more feasible than on small woodlots. However, 90 percent of the forest land in the Appalachian area is owned by private individuals and much of it is in small holdings. Studies have shown that even among these private owners few have single objectives in land ownership. Ordinarily they voice two or three objectives; often these objectives are not clearly defined.

This publication is intended to broaden the forester's perspective in evaluating the suitability of tracts for a variety of uses and use mixes. It should help the landowner crystalize reasonable expectations about the potential of his tract to satisfy some of his objectives. Also, it should be a valuable communication aid between the forester and the landowner.

The management options presented apply to the forest ecosystems that predominate in the central Appalachian region. These are the basic forest land units we chose to use in comparing and evaluating the effects of the various practices on the four forest resources. The seven forest ecosystems, which are described in detail later on, are: (1) oaks, (2) Appalachian mixed hardwoods, (3) northern hardwoods, (4) white pine, (5) Virginia pine, (6) red spruce, and (7) floodplain hardwoods. The ecosystem format is a compromise that caused the authors to speculate to some degree because available research information, particularly for wildlife and visual appeal, was not accumulated in the context of these particular ecosystems.

For brevity, only the common names of plants and animals are given. The names of most of the trees and some shrubs are those preferred in the *Check List of Native and Naturalized Trees (Little 1953)*. However, in some cases we used the locally accepted common names of trees. For other plants our authority was *Flora of West Virginia (Strasbaugh and Core 1952-64)* whose nomenclature is based on *Gray's Manual of Botany (Fernald 1950)*.

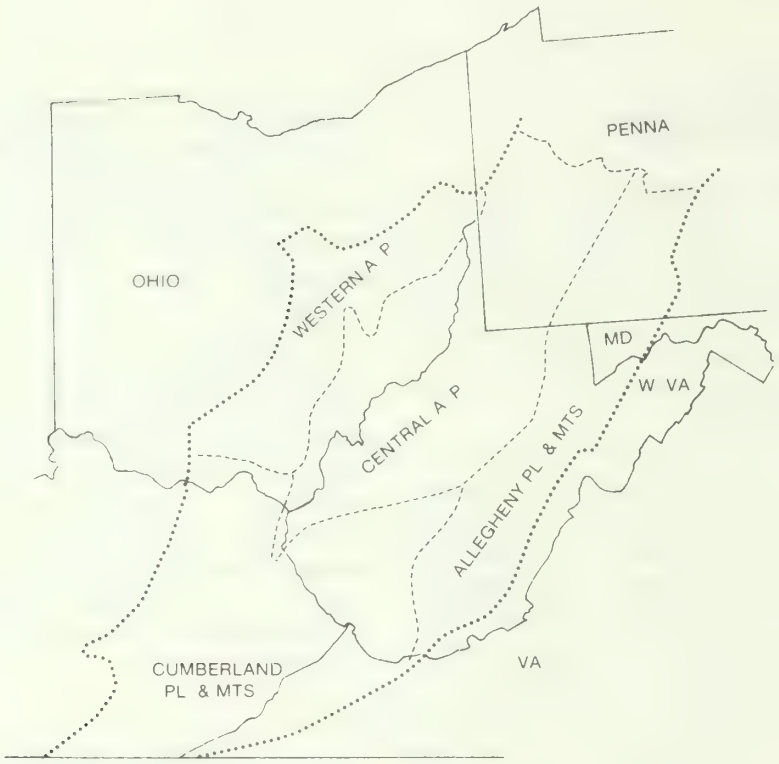
## Description of the Area

The central Appalachian region includes most of West Virginia and parts of the five adjacent states (fig. 1). Unifying features of the region are that it was once a nearly level plateau underlain by sedimentary deposits (including coal, gas sands, limestone, salt, and other minerals); it has not been glaciated; but it has been severely dissected by streams. The long eastern and western boundaries are distinct with respect to topography and land uses, but the northern and southern limits were chosen somewhat arbitrarily.

The region encompasses about 80 percent of four Appalachian land resource areas described by Austin (*1965:55-57*) (fig. 2): eastern Allegheny Plateau and Mountains, central Allegheny Plateau, western Allegheny Plateau, and Cumberland Plateau and Mountains.

The broad social and economic situation in central Appalachia has been discussed by many authors and will not be repeated. Instead the status of four forest resources is summarized in the "Rationale" section, and

Figure 1.—Land Resource areas in the central Appalachians.




here we summarize forest survey data which have not been previously published for central Appalachia as a unit (see Appendix for details).

Two-thirds of the 35-million-acre central Appalachian area is forested. Forestation is greatest in West Virginia, Virginia and Kentucky (75 to 80 percent), and least in Pennsylvania and Ohio (about 52 percent). Nearly all the forested area is classed as commercial forest land (land that is producing, or physically capable of producing, crops of industrial wood, and that is economically available now or prospectively). Less than 200,000 acres of woodlands have either been officially withdrawn from timber utilization or are incapable of yielding industrial wood products (Appendix, table 10), but many more are not available for commercial timber production because the owners are not interested in selling timber.

Nearly half of the commercial forest land is occupied by sawtimber stands—those at least 10 percent stocked with suitable growing-stock trees, with half or more of the stocking in sawtimber or poletimber trees, and with sawtimber stocking at least equal to poletimber stocking. Sawtimber is least abundant in Ohio (where it is about 30 percent of the commercial forest area) but constitutes 42 to 52 percent of the forest area in the other five states. The remainder of the commercial forest area is divided between poletimber (23 percent) and seedling or sapling stands (29 percent). About half a million acres is classed as nonstocked; that is, in stands less than 10 percent stocked with growing-stock trees (Appendix, table 12).

The pattern of forest ownership is a mosaic of small holdings (Appendix, table 11). Almost 90 percent of the land belongs either to farmers (35 percent) or "miscellaneous private owners" (54 percent). Forest industries hold only about 820,000 acres (4 percent) of the total. the remaining 7 percent is either in National Forest (1,008,000 acres), or other public ownership (620,000 acres).

Ownership objectives have not been measured for central Appalachia as a separate unit, but the results of a West Virginia survey (*Christensen and Grafton 1966*) show that among all classes of private woodland owners, including industrial ownerships, objectives of ownership were ranked as follows: (1) wildlife, (2) timber for own use, (3) soil protection, (4) pasturage, (5) recreation, (6) watershed, (7) timber for sale, (8) secondary products for own use.

Forest-type acreages reported in timber resource bulletins were difficult to adapt to the forest ecosystems defined here. Many local forest types (such as white oak, northern red oak, yellow-poplar oak, sweetgum yellow-poplar, and various combinations) made up the oak-hickory major forest type and accounted for nearly two-thirds of the total commerial forest area. These types are the ones in which oaks or hickories, singly or in combination, make up a plurality of the stocking. Next in rank is the general type maple-beech-birch (mostly the local cherry-maple type) which occupies about 14 percent of the commercial forest land. The only other type that occupies more than 5 percent of the area is ash-elm-red maple. It occurs mostly on floodplains and in cold wet upland depressions. The oak-pine and pitch-shortleaf-Virginia pine forest types each occur on 4 to 5 percent of the area. The remaining acreage (4 percent) is split among aspen-birch, white pine, oak-gum, and spruce forest types (Appendix, table 13).

## Rationale for Multiple-use Considerations

To compare and discuss multiple-use options within a framework meaningful for the four resources we had to be concerned with a wide range of systems for managing forest lands. Thus we recognized that the optimum system for any one multiple-use may diverge greatly from the optimum for another use. Because forest manipulation for any use depends largely on cutting trees, operations which return a profit from timber harvesting usually offer the most practical vehicle for manipulating forest stands. In all, three generalized systems were rated:

(1) Even-aged management, involving growing and harvesting trees of the same age.

(2) Uneven-aged management, involving periodic harvesting in the same stand of selected trees of different ages.

(3) No commercial forest cutting, leaving the stand intact or at most involving removal of certain designated stems.

Within these three management options, we felt that we could consider most types of operations aimed at enhancing the four resources: timber, water, visual appeal, and wildlife.

We did not feel that it was desirable within the scope of this paper to discuss in detail or to present guidelines for all the elements inherent in the various proposed systems. For example, good road management—which is pertinent to management for all the resources—was not discussed simply because the technical principles are known and available. Likewise control of wildfire, extremely important to the practice of forestry for any purpose, was not discussed since methods of applying proper fire control are available. In the same way, procedures for elimination of roadside debris and thinning forest stands are examples of the types of practices for which information would ordinarily be available to practitioners or could be worked out for the local situation based on established principles. Thus failure to prescribe methodology in these areas was not due to lack of recognition of their importance but to the belief that it was unnecessary.

In the following, we discuss our rationale as developed separately for each resource.

### TIMBER

Timber is an important crop in the central Appalachians. A large number of commercial species are found in several widely diverse ecosystems. Many of these species are valuable hardwoods, badly needed in the wood economy of the Nation. The complexity of species mixtures and the variability in site quality combine to give us some of the most productive stands in the Nation and some of the poorest.

Overall, however, productivity is good; and prospects for profitable timber management are encouraging.

It is not practical to describe in detail in this paper all the potential ramifications of forestry operations that exist under the wide range of physical and economic conditions. For simplicity, the forestry operations are grouped under two main management systems—even-aged and uneven-aged. Within these two systems, forest practices will vary from crude to highly intensive and will be adjusted to meet the variations in sites, stand conditions, markets, and owner objectives (both private and public). Within these constraints, and within the limitations imposed by the other-than-timber demands on the forest resource, our recommendations assume the practice of the best silviculture possible.

Because this is a discussion of options, we had to develop a framework for timber operations that rated stumpage returns relative to different broad kinds of practices. In the framework we chose, all considerations are relative *within* an ecosystem and a site class, and we could ignore to a certain extent the differences in stumpage returns among ecosystems and sites. The following generalized relationships formed the bases for rating stumpage returns:

1. Even-aged systems are more profitable than uneven-aged systems.

2. Within even-aged systems, large clearcuts are more profitable than small ones.

3. Again within even-aged systems, for the rotations cited, the shorter rotations yield higher rates of return than the longer rotations.

4. Where uneven-aged management is practiced (and for the range of tree sizes cited), a low rate of return is correlated with the larger-sized harvestable trees and a high rate of return is correlated with the smaller harvestable trees.

The rotation ages given for comparative purposes were based on rate of return (financial maturity) studies (*Trimble and Mendel 1969; Mendel and Trimble 1969; Grisez and Mendel 1972; Mendel, Grisez and Trimble 1973*). Because changing costs and returns can alter specific rates, it is best to think of these rotations as characterized by high rates of return, medium rates of return, and low rates of return. Actually the shortest rotation is predicated on harvesting the trees when they no longer return 6 percent for sawtimber; the medium-length rotation is predicated on a return rate of 4 percent; and the long rotation is based on a 2 percent return. The rates of return refer to the earning power of individual sawtimber-sized trees based on their current value and their increase in value annually for the next 10 years.

The rotation length associated with the 6 percent rate of return would be the first choice where only timber is important to the landowner. But, the longer rotations (lower rates of return) merit consideration where other resources are also important—say where the landowner wants more mast production for wildlife. In such cases, one might even want to know the tree diameters associated with the zero rate of financial return from timber. However, for technical reasons, the tree diameters calculated for return rates approaching zero tend to be unrealistic. The zero rate occurs when the rate of value deterioration equals the rate of value growth. A tree may reach its maximum physiological age or size before this happens, and calculated diameters for low return rates such as 0.5 percent may be 40 to 50 inches—clearly larger than the maximum size generally reached by many species.

This is not a serious barrier to using information about the low rates of return on timber. The 2 percent rate, in particular, is appropriate for planning multiple-use management where nonmonetary benefits may compensate for reductions in financial return.

Reducing the size of the area harvested in a single clearcut below some practical minimum reduces the net stumpage and the percentage return because of increased forest management and harvesting costs. An additional disadvantage of small clearcuts in hardwood stands is increased border-tree degrade from epicormic branching—the smaller the size of clearcuts made to harvest a given acreage, the greater the length of border and the larger the number of border trees exposed to epicormic branching.

Uneven-age management with selection cutting is generally considered to involve higher management and harvesting costs than even-aged systems. As with even-aged management, guides were set based on financial maturity. Growing the trees to the greatest age and size indicated is based on a low rate of return, and growing them to the smallest size shown is based on a high return. The ages and dbh's given in the tables are for the average size of the sawtimber trees harvested. The assumption is made that in marking these stands silvicultural considerations will be stressed.

For some ecosystems, financial maturity information was not available as a basis for recommendations for either even-aged or uneven-aged systems, and for some it was not appropriate. In these cases, other considerations were used and these are described in the separate ecosystem discussions.

## WATER

Most of this region receives at least 40 inches of well-distributed precipitation annually, the basis of a water resource ample for most local needs. Many perennial streams rise in forested hills and mountains of the central Appalachian region. Water in these smaller streams is abundant and clean. It contributes substantially to domestic and public supplies. But downstream from residential and manufacturing areas, most larger streams are polluted by acid drainage from coal mines and mine wastes, or by industrial and domestic wastes. Ground water often is accessible through deep wells but may be polluted by high mineralization. The technical know-how is available to decontaminate all of these water supplies, although many of the processes are expensive and seldom used when alternative supplies are available. These summary statements illustrate the major water problem of the central Appalachians; there is plenty of water but too often it is unusable without costly treatment.

Research has, however, tested several methods of forest management that improve, or at least maintain, the upstream water resource. Flow in headwater streams is increased by tree cutting (*Douglass and Swank 1972*). At least 20 percent of the basal area on a given watershed must be cut to cause a measurable flow increase and at least half of it must be cut to achieve an increase of useful size. Forest regrowth is so rapid in the central Appalachians that increases following partial cutting rarely persist for more than 2 years thereafter. Maximum increases, on the order of 10 or more inches during the first year after treatment, are possible after cutting all of the vegetation on a given watershed. But again, so rapid is forest regrowth that, even after clearcutting, flow increases taper off quickly and usually are inconsequential 6 years later. There is some evidence (*Hibbert 1967*) that north-facing slopes are more responsive to treatment than those facing south, an effect likely to be restricted to the steepest of mountain land.

Several useful generalizations are known concerning timing of streamflow increases from cutover forest land. All of them are predicated on maintaining a fairly continuous litter cover over the soil, and on maintaining the high infiltration rates characteristic of forest land. There is little question that most flow increases occur during the growing season, reflecting the fact of reduced transpiration and rainfall interception losses that greatly augment the soil moisture (*Patric 1973*) from which most headwater streamflow is derived. With augmented soil moisture, stormflow is higher from cutover forest land—but only during the growing season. Dormant season stormflow usually is little influenced by forest cutting because, in the humid climate of the central Appalachians, soil moisture in the dormant season is at near-maximum levels everywhere, regardless of forest cover. There has been considerable speculation that snowmelt might be desynchronized by judicious forest cutting, thereby lessening snow-melt floods, but it is now felt (*Federer et al. 1972*) that this form of flood regulation is impractical in the eastern United States.

Timber harvest often has detrimental though preventable effects on quality of streamflow. Water temperature increase accompanying heavy cutting near streams is prevented by retaining an uncut or lightly cut strip of trees to shade channels. There is evidence of increased chemical content in New

Hampshire streams after heavy cutting (*Pierce et al. 1972*), although a review of research (*U.S. Forest Service 1971*), showed no similar effects elsewhere in the country. Fire is currently regarded as of negligible importance to water quality in this region. Increased turbidity caused by eroded soil and organic matter has been and remains the paramount threat to water quality in forest streams. Tree cutting per se, even clearcutting, does not cause soil erosion but careless logging can and does, regardless of the silvicultural systems applied. Again, the critical need is to maintain the high infiltration rates characteristic of litter-covered forest land. Road building and log skidding push aside the protective litter, exposing the underlying mineral soil to erosion. Methods both to prevent and to control such erosion and associated damage to water quality are known (*Kochenderfer 1970*) but all too often are regarded as too costly and are not applied. The key is intelligently regulated road and logging practices which, if followed, will assure streamflow of continued high quality. Otherwise, impairment of forest water quality is certain.

The preceding paragraphs summarize years of research concerning timber harvest effects on quantity, timing, and quality of forest water resources. These results have been achieved repeatedly in dozens of carefully controlled experiments. But it is commonly found that many experimental results, particularly the effects of forest cutting on amount and timing of streamflow, seldom are demonstrated on nonresearch watersheds. The reason, often not appreciated by the nonscientist, is that lack of experimental control in routine forest operations minimizes most opportunity to duplicate research results. It is not realized that a multitude of interacting influences, in addition to whatever forest management measure is applied, actually control streamflow from any forested watershed.

Given carefully applied watershed treatments, the universal condition of diversity virtually assures a minimum of water response to management in central Appalachian streams of greater than first-order magnitude. Diversity among tree species, sizes, and ages is characteristic of the regional forest, each combination affording a different opportunity for management practices. Diverse topography and soil properties will cause a wide range of hydrologic response to the selected management practice.

Markets for forest products vary from place to place and from year to year, some affording opportunities for profitable timber harvest. Superimposed on all of these variables is the predominant pattern of land ownership, a mosaic of small holdings having little or no relation to hydrologic boundaries, with management applied to each holding likely to reflect different objectives of forest land ownership. Given such diversity, practices having one effect on water resources tend to be nullified by other practices having unrelated or even opposite effects. For a simple example, streamflow increases caused by cutting seem to be balanced by decreases accompanying tree regrowth elsewhere on large watersheds. The probability is slight that any practice, or even group of practices, will be applied within the requisite limits of time and space to cause significant response on any but the smallest of watersheds.

The public is likely to look askance at most efforts to augment forest water supplies by cutting, an unshakeable tenet of their faith holding that the uncut forest optimizes water resources. In this light, most tree-cutting will be seen as hydrologically undesirable, regardless of research results to the contrary. Since public acceptance of a controversial practice usually is necessary before it is widely applied, intensive forest management for more water remains well in the future. Moreover, water is so relatively abundant in the humid central Appalachians that any sacrifice for it of timber, wildlife, or recreational values also will be reckoned as undesirable on economic grounds. Given these value judgments, intensive forest management to produce more water is not likely, but managers must be prepared to deal constructively with increasing public concern for protecting water quality.

In subsequent sections, a number of forest practices are assigned desirability ratings as to their influence on forest water resources. Ordinarily, those practices are considered desirable that:

1. Increase water productivity. Here, cutting practices are ranked most desirable as they decrease evaporative losses and correspondingly increase streamflow. Streamflow is maximized by eliminating all cover or by converting a forest ecosystem to some permanent low cover such as grass, but this conversion is costly and unwarranted in view of water abundance in the central Appalachians.

2. Protect water quality. Those practices causing least frequent and extensive exposure of mineral soil are rated most desirable. Water quality ordinarily is maximized on forest land by maintaining an unbroken tree and litter cover but this practice too is prohibitively costly in terms of other resource values necessarily foregone in its application.

3. It is further assumed that all forest practices will embody silviculturally acceptable techniques and that the accompanying logging and road practices will be regulated carefully and intelligently.

It will be noted that those practices tending to increase water productivity tend decreasingly to protect its quality. However, we know that use of silviculturally acceptable techniques to harvest forest products harms water quality so little that it remains fit for most human uses without additional purification. Thus, implementation of existing knowledge permits forest products harvest with some possibility of increased streamflow but without serious impairment of water quality. At this stage in the evolution of forest management in the central Appalachians, there is sufficient water to meet human needs; quality protection of existing resources is the most important hydrologic task facing forest managers.

## VISUAL APPEAL

The visual appeal of a forest environment is influenced by existing resource configurations and by man-made changes. Whatever a particular ownership objective may be, a single common thread in managing for social uses of forest resources is to provide a visually appealing forest environment. The truly creative part of forest management, while meeting demand for all products, is to promote perception of intangible values—such as visual appeal (*Titus 1967*).

Timber harvests influence visual appeal of both the forest landscape and the forest "on site". The forest landscape, as used here, refers to the forest as viewed from a distance, and the forest on-site refers to the forest as seen from within.

Sharp breaks in the characteristic central Appalachian forest landscape are relatively rare. When man-made changes are introduced into the landscape, such as forest harvest patterns or logging access roads, visual landscape harmony may be damaged. In central Appalachia, as elsewhere, large clearcuts have had a negative impact on landscape appeal. Forest harvesting practices that promote either excessive homogeneity or heterogeneity in the characteristic forest landscape should be avoided (*Shafer 1967*).

Any forest practice that involves timber removal has an influence on landscape appeal. Skid trails are needed to collect felled timber and access roads must be constructed. But a considerable range exists in the overall effect of any one forest practice on landscape appeal. Carefully planned timber harvests, if conducted in harmony with the characteristic forest landscape, may have little influence on landscape visual appeal (*U.S. Forest Service 1973*). For example, by limiting the size of clearcuts, creating irregularly shaped units, and feathering the edge of clearcut units into the surrounding forest, the influence of clearcutting on landscape appeal may be eliminated or clearcutting even may improve visual appeal by creating needed diversity in monotonous forest landscapes. Single tree and group selection cuts, too, can be conducted to minimize the effect of timber removal on landscape values.

Both landscape and on-site visual appeal may be enhanced by growing large trees. Thus, forest management systems with long rotations promote a more appealing forest landscape than those with short rotations, because larger trees occupy the landscape for longer periods and the forest will be disturbed only at long intervals.

The on-site visual impact of various harvesting methods depends on the harvest system used, the reproductive capacity of the site, and post-logging practices conducted to minimize site damage. Varying degrees of on-site disruption are inherent in each harvesting method. However, proper skid trail management, spreading of slash and other logging debris, and the felling of damaged and dead trees are all practices that can help minimize the visual impact of logging. The duration of visual site damage or disruption depends largely on the reproductive potential of the site and on the post-logging practices used to encourage rapid site recovery.

There is much disagreement about the visual impact of forest practices on the forest landscape and forest site. Any system designed to evaluate the visual effects of timber harvesting on visual appeal must be highly subjective and open to meaningful criticism. Research has not yet developed "aesthetic recovery charts" to relate the effects of forest harvesting over time to visual appeal. Table 1 describes the general visual effects of forest cutting practices that were used to make the visual impact evaluations contained in this guide. Specific criteria used to evaluate harvest practices subjectively within forest ecosystems were as follows:

A forest practice was judged to maximize visual appeal (or have the least negative visual impact) if:

1. A relatively small forest area is affected.
2. Cutting patterns complement the shape and form of characteristic forest openings.
3. The practice favors rapid vegetative regeneration and growth.
4. The practice allows larger trees to occupy the site for long periods.
5. The practice allows for maximum time between cuttings so that forest cover will occupy the site as long as possible.
6. Physical site damage is minimized.
7. The practice occurs on relatively fertile sites.

## WILDLIFE

Hunting and fishing have received substantially more attention than non-consumptive enjoyment of wildlife, but both kinds of use have been increasing. Hunters in the region include about 400,000 resident licensees, an unknown number of unlicensed people (prob-

Table 1.—*Effects of forest harvesting practices on visual appeal*[a]

| Forest practice | Effect on visual appeal | |
|---|---|---|
| | Forest landscape | On-site impact |
| Uneven-aged management with selection cutting | Maintains characteristic visual landscape character and unity. Has least visual impact compared to other commercial harvesting practices. | Relatively short-term effects. If properly done, can improve on-site visual appeal. |
| Even-aged management with clearcutting—"Naturalistic" clearcuts.[b] ½—1 Acre | If natural openings occur, can emulate characteristic landscape patterns and satisfy landscape expectations. May enhance landscapes with little variety. | Difficult to eliminate visual effects of logging. Residual slash may be visible for 3 to 5 years. |
| Clearcuts of 25 acres or more | May enhance landscapes with little variety, but more typically results in visual disharmony. | Limited opportunities to minimize visual impact of logging. Residual slash may be visible for 3 to 5 years. |
| No commercial harvest | Maintains characteristic landscape. | No effect; or by judicious cutting on-site appeal may be improved through reduction in forest density or removal of unsightly snags. |

[a]Material adapted from Forest Landscape Management, Vol. 1, 1972. USDA Forest Service, Northern Region.

[b]Clearcuts made with attention to preserving natural landscape character. Attempt made to shape clearcuts and cut patterns to promote landscape harmony.

ably about 80,000) who hunt only on their own lands, and a relatively small proportion of non-resident licensees. Perhaps 700,000 people engage in non-consumptive recreation activities that largely concern wildlife and woodlands. We have no local estimates of these activities but nationally the participation ratios *per 100 hunters* were 146 nature walkers, 36 birdwatchers, and 23 wildlife photographers (*Fish and Wildlife Service 1970*). Numbers of people derived from such estimates should not be added, however, because many individuals fit into more than one category.

Among all ownership objectives of forest landowners in West Virginia, wildlife was important to 62 percent of the owners—more than any other objective (*Christensen and Grafton 1966*). Concern among biologists and the public about forest habitat management centers on gray squirrels and wild turkeys in all states. There is less concern about habitat of deer and the other game animals (except bear in West Virginia), and little concern about non-game, forest-dwelling animals. The popularity ranking by hunters for forest game animals (in West Virginia) is squirrels, deer, ruffed grouse, wild turkey, raccoon, bear, woodcock and snowshoe hare.[1] Hatchery-reared rainbow trout are the most popular forest-related fish; few streams support the native brook trout or naturalized rainbow trout.

Most authorities agree that wildlife habitat can be most efficiently maintained or improved by coordinating timber and habitat management so that timber returns pay part or all of the habitat management cost. Accordingly, the wildlife habitat evaluations herein relate mostly to commercially feasible timber management options plus some that may be nearly marginal, at least. Direct management practices such as seeding log roads and putting up nest boxes are not discussed nor is regulation of animal numbers, control of access, local problems concerning certain animals, and such. These omissions do not mean that we consider such practices or problems unimportant.

The framework chosen for relating timber and wildlife evaluations was the "ecosystem", as indicated by forest overstory type and timber site characteristics. Although this framework was considered the best one for timber and wildlife purposes combined, it has deficiencies for evaluating wildlife habitat relationships. The most serious flaws stem from the mobility and adaptability of wildlife and the fact that few kinds of animals are restricted to any one ecosystem throughout the year. How then do we deal with mobility factors and other variables peculiar to wildlife but not to timber? Complete discussion within a tree-oriented framework is impractical.

Instead, the discussion is limited to general statements about the sets of variables considered to be most common. The risk in this approach is obvious—some of the evaluations given will be inaccurate for some individual forest properties and sets of land-owner objectives. The evaluations should not be taken as challenges to local judgments concerning specific woodlands or to habitat problems that are outside the scope of this paper.

Another simplification was necessary. To reduce the complexity and variability in habitat requirements among some 250 wildlife species, they were separated into two groups called "edge" and "interior" species. Edge species are those associated more with forest edges, openings, shrub cover, and understory plants than with maturing and old forest stands. The animals considered typical were deer, grouse, rabbits, and many non-game bird species—about two-thirds of which nest within 20 feet of the ground. The typical "interior" species are gray squirrels, turkeys, and canopy-nesting birds such as the broad-winged hawk, Baltimore oriole, and others. But consideration was not limited to the named, typical species, and need not be. Although any one species can be a useful model in planning or evaluating habitat management, each species has habitat requirements sufficiently like those of several other species that they can be considered collectively.

Readers may question many of the evaluations; few are technically documented, and

[1]Riffe, Jan E. 1971. *Hunting survey*. W. Va. Dep. Nat. Resour. Wildlife. Res. Div. Unpublished report FW-4R-2, III-I.

practically none has been rigorously proven on the ground. Lacking proofs, the evaluations are simply judgments based on relating knowledge of animal needs and preferences against knowledge of habitat conditions. Preliminary judgments were compared with the information in a recent handbook: USDA Forest Service. 1971. WILDLIFE MANAGEMENT HANDBOOK — SOUTHERN REGION. FSH 2609. 23R., Atlanta, Ga. These initial judgments were revised following consultation with several biologists.

## Method of Presentation

We have rated the seven forest ecosystems that make up most of the forest land in the central Appalachians with respect to their potential importance as producers of timber, water, visual appeal, and wildlife (table 2). These ratings are intended only to provide landowners with some relevant options. To some extent, different factors determined the ratings for each resource. For example, for timber we considered such factors as unit productivity (quantitative and qualitative), aereal extent, existing stand conditions, and estimated future importance. We emphasize that landowners, with their own special point of view, may logically take exception to many of the ratings that we have assigned.

For each of the ecosystems, we rated forest practices as to their effect on timber, visual appeal, water, and wildlife (tables 3 to 9). The ratings in each table permit the manager to compare — within the ecosystem — the

Table 2.—*Importance of the Ecosystems for timber, water, visual appeal, and wildlife*

| Ecosystems | Resources | | | | |
|---|---|---|---|---|---|
| | Timber | Water | Visual appeal | Wildlife | |
| | | | | Edge species | Interior species |
| 1. Oaks: | | | | | |
| Fair site[a] | M[b] | M | M | H | H |
| Poor site | L | L | L | H | H |
| 2. Mixed Appalachian hardwoods: | | | | | |
| Excellent site | H | H | H | H | M |
| Good site | H | M | M | H | M-H[c] |
| 3. Northern hardwoods: | | | | | |
| Excellent site | H | H | H | H | M |
| Good site | M | M | M | H | M |
| Fair site | L | M | M | H | M |
| 4. White pine: | | | | | |
| Good site | M | H | H | M | L |
| Fair site | M | M | H | M | L |
| Poor site | L | L | M | M | L |
| 5. Virginia pine: | | | | | |
| Fair site | L | L | M | M | M |
| Poor site | L | L | L | M | L |
| 6. Red spruce: | | | | | |
| Good site | L | H | H | L | L |
| Fair site | L | M | H | L | L |
| Poor site | O | M | M | L | L |
| 7. Floodplain hardwoods: | L | H | H | M | L |

[a]Site quality refers to the timber-growing potential of the area. Sites are oak site indexes based on Schnur (1937) and related to land features (Trimble and Weitzman 1956). With the use of the interspecies relationships developed by Doolittle (1958), and a little extrapolation, they were adapted to all ecosystems except floodplain hardwoods. The scale of oak site indexes corresponding to the descriptive terms used is as follows: excellent site = 75 ft. +; good site = 65-74 ft.; fair site = 55-64 ft.; and poor site = 45-54 feet.

[b]H (high), M (medium), L (low), and O (none or insignificant).

[c]Rating higher where oaks predominate; this ecosystem intergrades with the oak type.

Table 3.—*Effects of oak management on forest resources—a desirability rating*
[For rating explanation, see page 16]

| Forest practice | Size of cleared areas | Rotation length or average age and dbh of crop trees | | | | Timber: maximizing stumpage returns | Water | | Visual appeal: landscape and on-site quality | Wildlife | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fair site | | Poor site | | | Productivity | Quality | | Edge species | Interior species |
| | | Age | Dbh | Age | Dbh | | | | | | |
| | *Acres* | *Years* | *Inches* | *Years* | *Inches* | | | | | | |
| | | | | | | OBJECTIVE: SAWLOGS | | | | | |
| Even-aged management with clearcutting | ½-1[a] | 115 | 22 | — | — | + | 0 | +++ | ++++[b] | ++ | +++ |
| | | 95 | 18 | — | — | + | 0 | +++ | +++ | +++ | ++ |
| | | 85 | 17 | — | — | ++ | ++ | ++ | +++ | +++ | ++ |
| | 5 | 115 | 22 | — | — | + | 0 | +++ | ++ | ++ | (++++) |
| | | 95 | 18 | — | — | ++ | ++ | +++ | + | ++++ | ++ |
| | | 85 | 17 | — | — | +++ | ++ | ++ | + | +++ | ++ |
| | 25 | 115 | 22 | — | — | ++ | ++ | +++ | + | ++ | ++ |
| | | 95 | 18 | — | — | +++ | ++ | +++ | + | ++ | + |
| | | 85 | 17 | — | — | ++++ | +++ | ++ | + | ++ | + |
| Uneven-aged management with selection | — | 135 | 22 | — | — | + | 0 | ++ | ++++ | + | (+++) |
| | — | 115 | 18 | — | — | + | 0 | ++ | +++ | ++ | ++ |
| | — | 105 | 17 | — | — | ++ | 0 | ++ | ++ | ++ | ++ |
| | | | | | | OBJECTIVE: PULPWOOD | | | | | |
| Even-aged management with clearcutting | ½-1 | — | — | 60 | 8 | ? | 0 | ++ | + | ++ | + |
| | | — | — | 50 | 7 | ? | 0 | ++ | + | ++ | + |
| | 5 | — | — | 60 | 8 | ? | 0 | ++ | + | ++ | + |
| | | — | — | 50 | 7 | ? | ++ | ++ | + | ++ | + |
| | 25 | — | — | 60 | 8 | ? | ++ | ++ | + | ++ | + |
| | | — | — | 50 | 7 | ? | +++ | ++ | + | ++ | + |
| No commercial harvest | — | — | — | — | — | 0 | 0 | ++++ | ++++ | + | (++++)[c] |

[a]Clearcutting in small areas such as these can be regulated as patch cutting with area control or group selection with volume control.
[b]Clearcuts to blend with natural landscape patterns as feasible.
[c]Assuming about 5 percent of area in openings with herbaceous or brushy covers.

Table 4.—*Effects of Appalachian mixed hardwood management on forest resources—a desirability rating*

[For rating explanation, see page 16]

| Forest practice | Size of cleared areas | Rotation length or average age and dbh of crop trees | | | | Timber: maximizing stumpage returns | Water | | Visual appeal: landscape and on-site quality | Wildlife | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Excellent site | | Good site | | | Productivity | Quality | | Edge species | Interior species |
| | | Age | Dbh | Age | Dbh | | | | | | |
| | *Acres* | *Years* | *Inches* | *Years* | *Inches* | | | | | | |
| Even-aged management with clearcutting | ½-1[a] | 90 | 26 | 105 | 25 | + | 0 | +++ | +++[b] | ++ | ++++ |
| | | 75 | 21 | 85 | 20 | + | 0 | +++ | ++ | +++ | +++ |
| | | 65 | 18 | 70 | 17 | ++ | ++ | ++ | ++ | +++ | ++ |
| | 5 | 90 | 26 | 105 | 25 | + | 0 | +++ | ++ | +++ | +++ |
| | | 75 | 21 | 85 | 20 | ++ | ++ | +++ | + | ++++ | ++ |
| | | 65 | 18 | 70 | 17 | +++ | +++ | ++ | + | +++ | + |
| | 25 | 90 | 26 | 105 | 25 | ++ | ++ | +++ | + | ++ | + |
| | | 75 | 21 | 85 | 20 | +++ | +++ | +++ | + | ++ | + |
| | | 65 | 18 | 70 | 17 | ++++ | +++ | ++ | + | + | + |
| Uneven-aged management with selection cutting | — | 125 | 26 | 135 | 25 | + | 0 | ++ | +++ | + | ++ |
| | — | 105 | 21 | 110 | 20 | + | 0 | ++ | +++ | + | ++ |
| | — | 95 | 18 | 100 | 17 | ++ | 0 | ++ | ++ | ++ | + |
| No commercial harvest | — | — | — | — | — | 0 | 0 | ++++ | ++++ | + | (++)[c] |

[a]Clearcutting in small areas such as these can be regulated as patch cutting with area control or group selection with volume control.
[b]Clearcuts to blend with natural landscape patterns as feasible.
[c]Assuming at least 5 percent of area in openings with herbaceous or brushy covers.

Table 5.—*Effects of northern hardwood management on forest resources—a desirability rating*

[For rating explanation, see page 16]

| Forest practice | Size of cleared areas | Rotation length or average age and dbh of crop trees | | | | | | Timber: maximizing stumpage returns | Water | | Visual appeal: landscape and on-site quality | Wildlife[c] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Excellent site | | Good site | | Fair site | | | Productivity | Quality | | Edge species | Interior species |
| | | Age | Dbh | Age | Dbh | Age | Dbh | | | | | | |
| | *Acres* | *Yrs.* | *In.* | *Yrs.* | *In.* | *Yrs.* | *In.* | | | | | | |
| Even-aged management with clearcutting | ½-1[a] | 100 | 28 | 110 | 27 | 135 | 26 | + | 0 | +++ | ++++[b] | + | ++++ |
| | | 70 | 20 | 80 | 19 | 95 | 18 | + | 0 | +++ | +++ | +++ | ++ |
| | | 60 | 17 | 70 | 17 | 85 | 17 | ++ | ++ | ++ | ++ | +++ | + |
| | 5 | 100 | 28 | 110 | 27 | 135 | 26 | + | 0 | +++ | ++ | +++ | +++ |
| | | 70 | 20 | 80 | 19 | 95 | 18 | ++ | ++ | +++ | + | ++++ | ++ |
| | | 60 | 17 | 70 | 17 | 85 | 17 | +++ | +++ | ++ | + | ++++ | + |
| | 25 | 100 | 28 | 110 | 27 | 135 | 26 | ++ | ++ | +++ | ++ | + | ++ |
| | | 70 | 20 | 80 | 19 | 95 | 18 | +++ | +++ | +++ | + | ++ | + |
| | | 60 | 17 | 70 | 17 | 85 | 17 | ++++ | +++ | ++ | + | ++ | + |
| Uneven-aged management with selection cutting | — | 135 | 28 | 145 | 27 | 155 | 26 | + | 0 | ++ | ++++ | + | ++ |
| | — | 100 | 20 | 110 | 19 | 115 | 18 | + | 0 | ++ | +++ | ++ | + |
| | — | 90 | 17 | 100 | 17 | 105 | 17 | ++ | 0 | ++ | +++ | ++ | + |
| No commercial harvest | — | — | — | — | — | — | — | 0 | 0 | ++++ | ++++ | + | + |

[a]Clearcutting in small areas such as these can be regulated as patch cutting with area control or group selection with volume control.

[b]Clearcuts to blend with natural landscape patterns as feasible.

[c]All ratings concern stands where cherry is to be favored; see text for different practices to favor beech and other species.

Table 6.—*Effects of white pine management on forest resources—a desirability rating*

[For rating explanation, see page 16]

| Forest practice | Size of cleared areas | Rotation length or average age and dbh of crop trees by white pine site index[a] | | | | | | Timber: maximizing stumpage returns | Water | | Visual appeal: landscape and on-site quality | Wildlife | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SI 75 | | SI 65 | | SI 55 | | | Productivity | Quality | | Edge species | Interior species |
| | | Age | Dbh | Age | Dbh | Age | Dbh | | | | | | |
| | *Acres* | *Yrs.* | *In.* | *Yrs.* | *In.* | *Yrs.* | *In.* | | | | | | |
| Even-aged management with clearcutting | ½-1[b] | 80 | 24 | 80 | 22 | 80 | 16 | + + | 0 | + + + | + + +[c] | + + + | + + + + |
| | 5 | 80 | 24 | 80 | 22 | 80 | 16 | + + + | + + | + + + | + + | + + + + | + + + |
| | 25 | 80 | 24 | 80 | 22 | 80 | 16 | + + + + | + + + | + + + | + | + + | + |
| No commercial cutting | — | — | — | — | — | — | — | 0 | 0 | + + + + | + + + + | + | (+ + +) |

[a]Site index for oak corresponding to site indexes for pine of 55, 65, and 75 are respectively 45, 55, and 65 (Doolittle 1958).
[b]Clearcutting in small areas such as these can be regulated as patch cutting with area control or group selection with volume control.
[c]Clearcuts to blend with natural landscape patterns as feasible.



Table 7.—*Effects of management for Virginia pine (and two other hard pines) on forest resources—a desirability rating*

[For rating explanation, see page 16]

| Forest practice | Size of cleared areas | Rotation length or average age and dbh of crop trees by Virginia pine site index[a] | | | | Timber: maximizing stumpage returns | Water | | Visual appeal: landscape and on-site quality | Wildlife | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SI 60 | | SI 50 | | | Productivity | Quality | | Edge species | Interior species |
| | | Age | Dbh | Age | Dbh | | | | | | |
| | *Acres* | *Years* | *Inches* | *Years* | *Inches* | | | | | | |
| Even-aged management with clearcutting and hardwood control | ½-1[b] | 45 | 9 | 45 | 7 | + | 0 | + | + + +[c] | (+) | + |
| | 5 | 45 | 9 | 45 | 7 | + + + | 0 | + | + + | (+) | + |
| | 25 | 45 | 9 | 45 | 7 | + + + + | + + | + | + + | + | + |
| No commercial cutting | — | — | — | — | — | 0 | 0 | + + + + | + + + + | (+ + +) | (+ + + +)[d] |

[a]Site indexes for oak corresponding to site indexes 50 and 60 for Virginia pine are 45 and 55 (Doolittle 1958).
[b]Clearcutting in small areas such as these can be regulated as patch cutting with area control or group selection with volume control.
[c]Clearcuts to blend with natural landscape patterns as feasible.
[d]Assuming about 5 percent of area in natural openings, with herbaceous or brushy cover.

Table 8.—*Effects of red spruce management on forest resources—a desirability rating*

[For rating explanation, see page 16]

| Forest practice | Size of cleared areas | Rotation length or average age and dbh of crop trees | | | | Timber: maximizing stumpage returns | Water | | Visual appeal: landscape and on-site quality | Wildlife | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Good site | | Fair site[b] | | | Productivity | Quality | | Edge species | Interior species |
| | | Age | Dbh | Age | Dbh | | | | | | |
| | *Acres* | *Years* | *Inches* | *Years* | *Inches* | | | | | | |
| Even-aged management with clearcutting | ½-1[a] | 120-150 | 22 | 120-150 | 16 | ++ | 0 | +++ | +++[c] | +++ | ++++ |
| | 5 | 120-150 | 22 | 120-150 | 16 | +++ | 0 | +++ | ++ | ++++ | ++ |
| | 25 | 120-150 | 22 | 120-150 | 16 | ++++ | ++ | +++ | + | ++ | + |
| Partial cutting | — | 150-200 | 22 | 150-200 | 16 | +++ | 0 | ++ | ++++ | ++ | ++ |
| No commercial cutting | — | — | — | — | — | 0 | 0 | ++++ | ++++ | + | (+++) |

[a]Clearcutting in small areas such as these can be regulated as patch cutting with area control or group selection with volume control.
[b]On poor sites the only forest practice feasible is "No commercial cut".
[c]Clearcuts to blend with natural landscape patterns as feasible.

Table 9.—*Effects of floodplain hardwood management on forest resources—a desirability rating*

[For rating explanation, see page 16]

| Forest practice | Size of cleared areas | Timber: maximizing stumpage returns | Water | | Visual appeal: landscape and on-site quality | Wildlife | |
|---|---|---|---|---|---|---|---|
| | | | Productivity | Quality | | Edge species | Interior species |
| Even-aged management with clearcutting | *Acres* ½-1 | + | ++ | ++ | +++ | +++ | ++ |
| | 1-5 | ++ | +++ | ++ | ++ | ++++ | + |
| | 5+ | ++++ | +++ | ++ | + | ++ | + |
| Selection cutting | — | + | ++ | ++ | +++ | (++) | +++ |
| No commercial cutting | — | 0 | 0 | ++++ | ++++ | (++) | (++++) |

general effects of various practices on the resources of interest. The comparisons should aid the owner in choosing his management options. The ratings and their symbols are:

| | |
|---|---|
| Excellent | + + + + |
| Good | + + + |
| Fair | + + |
| Poor | + |
| Either no impact or no return | 0 |
| Unknown | ? |
| Limited application | () |

A forest practice that is rated "excellent" in its effect on a resource is, from the standpoint of that resource, a most desirable practice. Conversely, a practice that is rated "poor" in its impact on a resource is a relatively undesirable practice as it pertains to that resource. Brackets used with the above ratings indicate particular situations which are discussed and qualified in the text.

Because of the detail involved, it was not feasible to display in a table all the modifications and alternatives possible within a management option. Accordingly, and as an aid in interpreting the tables, we included for each ecosystem a discussion of the effects of the forest practices on each resource. Used in conjunction with the tables, the discussions help the reader make a balanced appraisal of the effects of the practice.

We must emphasize that the ratings are comparable within but not among ecosystems. Failure to appreciate this noncomparability can mislead users of these tables because the relative importance of the resource varies greatly among ecosystems (table 2). For example, timber stands are scattered and small in the floodplain hardwoods in the central Appalachians, and stumpage return is relatively unimportant. But this ecosystem is important for visual appeal and edge wildlife species.

# Multiple-use Evaluations of Forest Practices by Ecosystems

## 1. THE OAKS

### Description of the Ecosystem

Oak-dominated stands on good to excellent sites are classed with Appalachian mixed hardwoods and discussed in the following section of this paper. Here, we restrict our definition of the oak ecosystem to stands on areas of the oak-hickory complex with site indexes below 65 feet for oak *(Schnur 1937)*. And for discussion purposes, we split these sites into two classes; fair—55 to 64 feet, and poor—45 to 54 feet. Although some oak stands are found also on the good sites (65+ site index) and some oak stands are found on sites below 45, most oak stands occur on areas between site index 45 and 65 and at elevations below 3,000 feet *(Core 1966)*.

The five widely-distributed upland oaks in this type are white, northern red, black, scarlet, and chestnut. Although less abundant, the hickories are consistent stand components. Other commonly found associates are blackgum, beech, red maple, sourwood, sassafras, black locust, and sweet birch.

Most of the species found in this ecosystem are in the middle range in shade tolerance as exemplified by the oaks and hickories. However, considerable difference exists among species. For example, scarlet oak is relatively intolerant compared to white oak and red maple. At the extremes, beech is very tolerant and black locust is very intolerant.

Red oak is the most demanding oak in terms of site quality and is more abundant on the higher quality sites. Scarlet and chestnut oak are more commonly found at the lower end of the site range *(Weitzman and Trimble 1957)*.

Throughout the lower half of their site range (45 to 54 feet site index), oaks are often found associated with pines; white pine in scattered locations throughout the region, and the hard pines in warmer locations mostly in the western and southern parts of the central Appalachians.

Compared to Appalachian mixed hardwoods, oaks commonly have less herbaceous vegetation in the understory but the shrub/vine layer may be as dense or denser. Sassafras is a key shrub or small tree, and some others are flowering dogwood, serviceberry, sumacs, hawthorns, redbud, and eastern hophornbeam.

Among the vines and small shrubs, mountain laurel and other ericaceous species usually predominate on the drier sites. Across all kinds of sites the most common low, woody plants in West Virginia oak types are: greenbriers, blueberries and huckleberries, grapes, blackberries and raspberries, mountain laurel, azaleas, roses, and teaberry. And more than 20 other small woody plants were found.[2]

## Evaluation and Discussion

*Timber.*—Oak stands make up the most extensive forest ecosystem in the central Appalachians. On the fair sites, the product objective should be sawlogs, with small products coming from thinnings, tops, and limbs. However, in stands growing in the lower part of the site range, pulpwood may be the product objective in some situations. The poor sites, oak site index 45 to 54, should be managed for small products. Following Roach and Gingrich *(1968)*, these sites should probably be managed for pulpwood on rotations of 40 to 60 years, unless conversion to pine is envisioned.

On fair sites and where markets are available, a thinning program is practicable and will increase total yields *(Gingrich 1971)*. Probably neither thinning nor other cultural operations are feasible on poor sites.

Again on fair sites, clearcutting offers the best opportunity for reproducing the moderately tolerant oaks — if advanced oak reproduction is on the ground at the time of cutting. Otherwise, a shelterwood cutting seems most promising, but research results are not available to define the timing or intensity of shelterwood cutting needed.

Individual tree selection cutting on fair sites will not reproduce a new stand in which there are many oaks. More tolerant species, especially red maple and beech, will make up a high proportion of the stand reproduced in this manner.

Group-selection cutting is an excellent reproduction method for oak stands which have large advance oak reproduction on the ground. But controlling the amount of area regenerated (small openings cut deliberately to favor the moderately tolerant oak) and regulating the rate of cutting for sustained yield are difficult and expensive; and the many small stands of different age classes make cultural and harvesting operations complicated and costly.

In determining the sizes of trees to be cut on the fair sites — for both even- and uneven-aged management systems — rate of return data were used (table 3). Such information was not available to apply to clearcutting pulpwood on the poor sites.

For sawtimber objectives, higher stumpage earning rates are favored by even-aged systems, by clearcutting larger areas, and by removing the trees at the smaller sizes.

For the pulpwood objective — suggested only for the poor sites — we had no economic data on which to base an appraisal of stumpage returns. However, hardwood pulp in the central Appalachians brings a low stumpage return and growth rates are very low on poor sites. This suggests that ratings for stumpage returns should be low in comparison with rating for the other resources — if these other resources are important. However, if these areas are managed for wood, returns will be increased by increasing the size of individual clearcuts.

*Water.*—The oaks predominate on exposed ridges above the mixed hardwoods and on warm, dry slopes. Evaporation is high on such sites, and with soils rockier and shallower than in mixed hardwoods there is less opportunity for rainfall storage, so streams originate far less frequently on oak sites. Cutting here has little potential to increase

[2]Wilson, H. L., C. M. Smithson, R. Kletzly, T. R. Samsell, K. Kruse, and G. Hubbard. 1951. *Cover mapping and habitat analysis.* Conser. Comm. of W. Va. Unpublished final report, Federal Aid in Wildl. Restoration Proj. 31-12, viii + 221 p. + 116 p. supplement.

streamflow, but from the standpoint of water quality the oak sites provide some of the best locations for logging roads (table 3). There is usually enough soil to shape an adequate road surface, enough stone to maintain a firm surface, and enough sun to dry it quickly. Roads on these sites have fewest drainage problems and do not erode easily, yet they are not so arid and infertile that revegetation is long delayed after logging.

*Visual Appeal.* — Oak stands, normally found on middle to upper slopes, are often quite visible. The oak forest is usually continuous with few natural or man-made openings. Because the ecosystem occupies a greater acreage in central Appalachia than any other type, it is basic to the overall landscape character of the region.

Forest practices that use longer rotations will result in larger trees and higher visual appeal. Large clearcuts are less visually appealing because of the disharmony they introduce in the characteristic landscape (table 3). But small to medium-sized clearcuts can often be used to enrich landscape diversity.

Clearcutting also allows for the control of stand succession and thereby maintains the characteristic forest type. Stand succession is more difficult to control with uneven-aged forest management. Application of uneven-aged management will result in a subtle change in the characteristic visual landscape. Selection cuttings, however, can overcome the disadvantage of large clearcuts by maintaining harmony in characteristic landscape patterns.

Even-aged management with a pulpwood objective has the same negative visual impact as clearcutting with a timber objective. The practice has the added disadvantage of producing smaller trees because of shorter harvest rotations.

The "no commercial harvest" practice could have either no effect or a desirable effect on visual appeal. No cutting at all would maintain the characteristic landscape. Judicious partial cutting, when made in appropriate situations to improve stand appearance, or to open up scenic views, would have an immediate positive impact on visual appeal.

*Wildlife.* — Although Appalachian mixed hardwoods and floodplain hardwoods are potentially more productive wildlife habitats, the oaks are by far the most common ecosystem in central Appalachia and for this reason the most important one for wildlife. Oak stands tend to be larger in area than those of other ecosystems, except northern hardwoods in the mountains. Since oak stands are common almost everywhere below 3,000 feet elevation, they may border any of the other ecosystems except spruce.

More species of upland wildlife are adapted to the oak ecosystem than to any other. The animals which interest people the most are squirrels and turkeys. Squirrels are periodically abundant in oak stands, but their numbers often fluctuate in a pattern lagging one year behind that of mast production. Turkeys are well adapted to the oak stands and the intergrading "good-site" mixed hardwoods. These are the best areas for turkeys where sufficiently extensive and undisturbed. Oak associations have a high potential for supporting increasing turkey populations on unoccupied and recently reestablished range in the hill country.

Many species of small birds and mammals thrive in oak stands. This is partly due to availability of hard mast; but perhaps more important is the quality of understory vegetation, as the oaks rank near the top among all ecosystems in density and variety of shrubs and vines.

In selecting tree species to favor, it's hard to go very wrong in an oak ecosystem. Generally, the pines and hemlock have less value for wildlife than hardwoods, but some portion of the stand, say 10 to 15 percent, may merit retention in softwood cover for variety and whatever shelter it provides. Among the hardwoods, mixtures of hickories and oaks with lesser numbers of the associated hardwoods are desirable. The red oaks generally fruit more consistently than the white oak species, and most stands should be managed to include both kinds in a ratio of two red to one white *(Nixon 1968)*. Exceptions are old stands of white oak that have an overriding aesthetic appeal, and chestnut oaks in some locations where they are better mast producers than

red oaks *(K. L. Carvell,* personal communication).

Within species of oaks, and hickories to a lesser extent, individual trees vary extremely in capacity for mast production. Those dominant and codominant trees that produce few nuts in good mast years are candidates for culling.

Stand size-class distributions that favor wildlife are essentially the same for oak and mixed hardwoods forests. Keeping about half of the stands in sawtimber-size trees is a reasonable compromise in meeting the conflicting habitat needs of species such as grouse and gray squirrels *(Shaw 1967)*. This sawtimber target and others each imply managing to attain a balanced mix of smaller trees. For example, on a fair site with even-aged management and a 125 year rotation, sustaining the sawtimber production requires approximately these percentages of the area in younger stands: seedlings—7, saplings—15, and poles—25. But these percentages would be higher on poorer sites, under shorter rotations, and in uneven-aged silviculture.

Because the oaks and good-site Appalachian mixed hardwoods are best for turkeys, squirrels and associated species—and these are premium animals in central Appalachia—sawtimber proportions exceeding 60 percent are often preferable. These larger sawtimber proportions imply low proportions of the brushy or herbaceous cover required by turkeys, for example. Special measures may be needed to maintain say 10 percent of the area in openings such as 0- to 5-year old clearcuts, small fields, and log roads and landings.

Silviculture should be keyed to maintaining mast production by oaks, hickories and the associated shade-intolerant or moderately tolerant species. Where there is risk that these species will eventually lose out to trees such as maples, beech, and hemlock, clearcutting followed by thinning is more effective in retaining them than is selection cutting or no commercial harvest. Clearcut patches can usually be larger than in Appalachian mixed hardwoods, simply because oak stands usually cover a larger area. But, as with other ecosystems, the width of clearcuts is more important than their area. Strips about 100 to 500 feet wide should be favored, allowing stand and operating conditions to determine the area of the individual strip and allowing the risk of browsing damage to regeneration to determine the total area cut in any one or two years. Clearcutting and weeding should be arranged to retain much of the understory, particularly the soft-mast producers (flowering dogwood, sassafras, grape, and others), except where aggressive competitors may seriously limit regeneration of oaks, hickories, and blackgum. Thinning at stand age 30 to 40 years or older can be designed to favor the better individual mast producers; and to do this, marking should be done during September or October in a good mast year.

Choice of rotation length depends on the wildlife objectives. Rotations of 150 to 200 years, or no cutting in some cases, are better for squirrels, turkeys and canopy-nesting songbirds, whereas shorter rotations—down to about 70 years—are better for forest edge species, including the majority of non-game birds. Pulpwood rotations, 50 to 60 years, would usually be inferior to schedules which allow a longer period of hard-mast production. The shortest rotations would favor some species of small birds, about two-thirds of which nest within 15 to 20 feet above the ground, but would not favor a diverse mix of wildlife species. For example, lack of large, old trees is detrimental to about 40 percent of non-game bird species (*Ray Evans, unpublished management guide*).

## 2. APPALACHIAN MIXED HARDWOODS

### Description of the Ecosystem

Appalachian mixed hardwoods is a forest complex found in moist locations and is characterized by great diversity in species composition. This ecosystem falls within the mixed-mesophytic complex described by Braun (*1950*). Appalachian mixed hardwoods are found in topographic coves, on lower slopes, on northern and eastern aspects, and on gentle terrain.

Typical soils are moderately deep, medium-textured, and well-drained. Abundant, well-distributed rainfall (*Yawney and Trimble 1968*) and limestone parent material (*Yawney 1964*) favor the occurrence of this type.

The stands may be composed almost entirely of red oak or yellow-poplar but a species mixture is typical; 20 or more commercial species may grow in the same stand. Among the more important trees are: yellow-poplar, sugar maple, northern red oak, hickories, black cherry, white oak, basswood, cucumbertree, white ash, red maple, sweet birch, beech, elm, and black locust. The mixtures vary with site quality, past treatment, elevation, and latitude. A few hemlocks and white pines are found within some stands.

Site quality ranges from good to excellent. In terms of the oak site index scale (*Schnur 1937*), the good sites are considered to cover the range from 65 to 74 feet while the excellent sites extend upward from 74 feet.

On excellent sites (above site index 74 for oak) yellow-poplar is the predominating species following heavy cutting, and in many areas yellow-poplar expresses a site index of well over 100 feet (*Doolittle 1958*). A number of other hardwoods valuable for timber are found in mixture.

The good site (between 65 and 74 site index for oak) is a transition zone between the mesophytic excellent site and the drier, oak-dominated fair site (site index 55 to 64 for oak). The species mixture is often greater than on either of the bracketing sites, with yellow-poplar often predominating at the upper end of the site range, and the oaks, particularly northern red oak, more numerous at the lower end of the range. Sites of this quality, which occupy somewhat less favorable topographic and soil positions than the excellent sites, probably cover a greater area in the central Appalachians than do the excellent sites.

Appalachian mixed hardwoods usually have a rich, varied understory and are noted for abundance of spring wildflowers. Spicebush is a key indicator shrub, and the typical large shrubs or small trees include flowering dogwood, sassafras, hawthorns, eastern hophornbeam, American hornbeam, striped maple, serviceberry, sumacs, and redbud. Among the lower-growing woody plants, vines often predominate over erect shrubs. In an unpublished West Virginia study the most common small woody plants in this and the red oak types were, in decreasing order: greenbriers, grapes, blackberries and raspberries, Virginia creeper, poison-ivy, blueberries, witch hazel, hydrangias, spicebush, azaleas, elderberries, teaberry and mountain laurel. About 30 other shrubs and vines also were recorded.[2]

## Evaluation and Discussion

*Timber.*—Appalachian mixed hardwoods grow on the best forest sites in the central Appalachians; this is our most profitable timber-producing ecosystem. Product objectives should be high-quality sawlogs and veneer logs; small products will come from thinnings, tops, and limbs. Intensive management with intermediate operations is profitable where a market for small products exists.

Because even-aged management favors the fast-growing high-value intolerants such as yellow-poplar and black cherry, and because both management costs and harvesting costs are lower with this system than with an uneven-aged system, even-aged management is preferable where wood production is the main objective. Within the even-aged system, rotations of three lengths and clearcut areas of three sizes are used for comparison purposes (table 4). Stand ages and average tree diameters were estimated from available growth information.

Because of high growth rates and valuable species, this ecosystem lends itself better than any other to intensive timber management. Where markets support thinnings, rotations for sawtimber may be as low as 60 to 70 years. However, with a thinning schedule heavy enough to appreciably shorten rotations, control of the tolerant understory will probably be necessary at harvest time to reduce such tolerants as sugar maple and beech to an acceptable proportion in the new stand.

Uneven-aged management with selection cutting is a less desirable system because it involves higher management and harvesting costs. Moreover, this system encourages a

stand of less valuable and slower-growing tolerant species such as maple and beech. Compared to even-aged systems, a longer period will be required for trees to reach harvestable size (table 4); and with the species favored, a higher proportion of the wood produced will be low value top and limb wood.

Group selection or patch cutting of small areas—½ to 1 acre—would permit the development of desirable yellow-poplar and black cherry, but the high management costs involved would almost certainly preclude the practice of intensive forestry for timber production.

*Water.*—Mixed hardwoods grow on cooler aspects, on relatively deep soils kept moist by drainage from soils upslope. These include the "coves", some of the most water-productive of upland sites, source areas of most springs and first-order streams in the region. Here, even-aged management can visibly increase growing season flow for 2 to 5 years after clearcutting—if all growth is cut in an entire cove. In general, flow is most increased by even-aged management and by clearcutting large blocks frequently.

Considerable erosion hazard must be expected on logging roads in moist cove soils. Many coves in the central Appalachians are underlain with limestone, and roads on fine-textured, relatively stone-free soils derived from it are easily eroded. The high timber productivity of coves also contributes to the erosion hazard by tempting loggers to return periodically for fast-growing, high-value timber, thus reopening roads to recurring possibilities of erosion. Seeps are common in coves, and logging roads across them must be drained and sometimes gravelled to prevent muddy and rutted surfaces. Damage to water quality is best avoided in coves by locating roads around identifiable trouble spots.

*Visual appeal.*—Where Appalachian hardwoods are found in topographic coves, the ecosystem is usually low in visibility and visual effects of cutting are not as severe as in more visible forest types. Because of the inherently high site productivity, the impacts of timber harvesting on visual appeal are likely to be of shorter duration than for ecosystems that normally occupy less productive sites.

Forest openings, such as those created through even-aged management, are likely to promote disharmony in the characteristic landscape pattern, because such openings are not normally found in the ecosystem. Because of the limited area normally covered by the ecosystem, the larger the opening created the more negative the visual impact (table 4). Even-aged systems with long rotations have less impact on visual appeal than even-aged systems with short rotations because the longer rotations produce larger trees that occupy the site for longer periods.

Selection cutting practiced with concern for natural landscape harmony can be used to improve visual appeal by eliminating unsightly stems or clearing to open up scenic vistas. The high regeneration capacity of the sites will further reduce the visual impact of selection cutting on the ecosystem. Selection cutting, although it does not result in as much immediate site disturbance as does clearcutting, will require disruption of the site at relatively short intervals. As in the case of clearcutting, growing trees for greater size will improve visual appeal.

The practice "no commercial harvest" could have either a positive effect or no effect on visual appeal. Cutting dead and dying trees, removal of vegetation to provide scenic vistas, and removal of vegetation to facilitate access, could increase visual appeal. Obviously, "no cutting" would have no impact on existing visual appeal.

*Wildlife.*—Potentially, Appalachian mixed hardwoods are better and more adaptable as wildlife habitat than any of the other systems described here. The primary advantages are: (1) soil fertility and moisture conditions capable of supporting a more lush and varied understory than any other system except floodplain hardwoods and (2) a large number of tree species. Secondarily, Appalachian mixed hardwoods increase the variety of total habitat where they intersperse with other systems—usually with the oaks.

Practically all species of forest wildlife frequent Appalachian mixed hardwoods, at least

occasionally. But the degree and importance of wildlife usage vary, depending on conditions around and within the type.

Because most individual stands are not large enough to furnish the complete seasonal or annual habitat requirements of the wider-ranging animals, the value of an individual stand depends on how well it supplements habitat conditions nearby. Conversely, the narrower-ranging wildlife species, notably most kinds of small birds during the nesting season, may find excellent, complete habitat within an Appalachian mixed hardwood stand.

The tree, shrub and vine species present within a stand also determine its value for wildlife. Paradoxically, the species typical of "good" sites provide better habitat than those typical of sites rated "excellent" for timber. The good sites are somewhat drier and less fertile and are likely to have more oaks and less yellow-poplar than the excellent sites.

Yellow-poplar, the key species in excellent-site Appalachian mixed hardwoods, has only moderate value for wildlife (recorded as food of 14 species). Other mast producers such as the oaks (particularly the red oaks), hickories, black cherry, beech, flowering dogwood, and even the maples are all superior to yellow-poplar for wildlife purposes and should be favored. But there are exceptions—small stands of yellow-poplar near extensive oak-hickory stands might supplement adjacent habitat. Small stands of white pine or hemlock within the Appalachian mixed hardwoods may similarly merit retention where they diversify the habitat.

Aside from such exceptional cases, stand conditions to favor as habitat for most wildlife species are those which maintain the greatest diversity of desirable mast producers. However, choices can be made in relation to differing preferences among wildlife species for various mixes of tree sizes (stand ages). For example, the habitat needs of gray squirrels versus grouse, or whippoorwills versus catbirds are so different that both kinds of species (interior and edge) cannot be ideally accommodated in the same stand. Perhaps the best compromise among these conflicting habitat needs would be the groups of stands that are produced through group-selection cutting. Thus stands of all size classes would be interspersed over short distances.

The wildlife habitat management choices range up to the maximum proportion of sawtimber attainable (probably 80 to 90 percent) for favoring gray squirrels, turkeys, etc., and down to a minimum desirable sawtimber proportion of 30 to 40 percent, to favor deer, grouse, the majority of non-game birds, etc. Within these choices of sawtimber proportions and emphasis on mast producers, shelter needs of the target wildlife species would usually be accommodated without any special measures. But in some Appalachian mixed hardwood stands, tree dens for squirrels and raccoons may be lacking due to causes such as high proportions of yellow-poplar. Replacement of some but not all of the poplar by better mast producers and by species that more frequently become den trees, such as oaks, beech, and maples, is a long-term remedy. For the short run, a few large den trees per acre, preferably of the better mast species, should be retained. Needs for "evergreen" cover will usually be adequately met by growth of hemlock and rhododendron, but these kinds of cover are of debatable value and beyond some minimum, covering say 10 to 15 percent of the area, should not be favored over either mast producers or thicket-forming vines and shrubs.

Choices among silvicultural practices to use in improving wildlife habitat are complicated by the variability among Appalachian mixed hardwood stands. The suggestions given in table 4 apply to stands including a mix of yellow-poplar, oaks, hickories, black cherry, and other trees, but no strong dominance by either yellow-poplar or sugar maple and beech.

In such stands, clearcutting in small patches and group selection cutting are good choices for maintaining a variety of species in the stand. Small patches in either system are preferable. For a given acreage cut in one year, several small patches (say 2 to 5 chains wide) give a better distribution of attractive habitat and put more of it close to adjacent cover than fewer large patches. Risk of damage to regeneration by browsing may be greater in the narrower patches, however. This risk has been low in most of central Appalachia, but must be judged locally. To guard against damages to

regeneration, patch width can be increased (*McGinnes 1969*).

For "edge" species of wildlife, shorter rotations are preferred although they involve sacrificing mast production and tree den sites in favor of understory food and cover. Conversely, longer rotations are preferred for habitat of squirrels, turkeys, canopy nesting birds, etc. For these species, in some stands, no cutting at all may be best for some period. But cutting or the equivalent will be required at some later stage to prevent replacement of the more valuable mix of intolerant and moderately tolerant tree species by sugar maple, beech, and hemlock.

Those early successional stage stands that are dominated by yellow-poplar can be changed through individual tree cutting to successionally more advanced stages. Clearcutting in successionally more advanced stands would tend to increase the proportion of the yellow-poplar. Stand composition more favorable to wildlife conceivably can be attained by such extreme measures as planting oaks, hickories, etc. and suppressing yellow-poplar, but this would rarely be practical. Perhaps the best practice for squirrels, turkeys, etc. would be to clearcut in small patches utilizing a very long rotation.

## 3. NORTHERN HARDWOODS

### Description of the Ecosystem

This widely divergent ecosystem is designated "northern hardwoods" for lack of a more appropriate title. This term is synonymous with the Forest Survey designation "sugar maple-beech-yellow birch." Actually, the following types of the northern forest region are included (*Soc. Am. Foresters 1967*): (1) hemlock-yellow birch, (2) sugar maple-beech-yellow birch, (3) sugar maple-basswood, (4) sugar maple, (5) black cherry-sugar maple, and (6) black cherry. The beech-sugar maple type of the central forest region is also represented.

Northern hardwoods are generally found at higher elevations in the central Appalachians. At its highest limits, the type may merge with red spruce or may occupy areas where red spruce was formerly abundant but has been depleted by cutting and fire. When found at lower elevations on the good and excellent sites, the type often merges with Appalachian mixed hardwoods; and, depending on cutting practices, may replace the typical Appalachian mixed hardwood mixture or be replaced by it.

Perhaps the most typical "northern hardwood" aggregation is the cherry-maple or Allegheny hardwood type—a second-growth forest type that owes its origin to lumbering and fire (*Braun 1950*). The type is composed primarily of black cherry, red maple, and sugar maple; with white ash, yellow and sweet birch, beech, and eastern hemlock as common associates (*Hough and Forbes 1943; Illick and Frontz 1928*).

The shade tolerance of a species largely determines its reaction to different silvicultural systems. The tolerance ratings of the most common northern hardwoods are (*U.S. Forest Service 1965*): *Tolerant*—sugar maple, beech, hemlock, spruce; *Moderately tolerant*—red maple, sweet birch, yellow birch; *Intolerant*—black cherry. Basswood is tolerant to moderately tolerant, and white ash lies between moderately tolerant and intolerant.

The northern hardwood ecosystem is found on excellent sites (site index 75 and better for oak), good sites (site index 65 to 74 for oak), and fair sites (site index 55 to 64 for oak). It may also occur to a limited extent on poor sites.

The understory of northern hardwoods typically includes about as many woody plant species as the Appalachian mixed hardwoods and oak ecosystems, but usually is less dense. Among the tall shrubs or small trees, mountain maple and serviceberry are key species and the other common ones are striped maple, chokeberry, sassafras, eastern hophornbeam, flowering dogwood, fire cherry, and sumacs.

Rhododendron and hobblebush virburnum are key plants among the lower-growing shrubs and vines. They and others, in approximate decreasing order of abundance are: blackberries and raspberries, greenbriers, witch-hazel, viburnums, hydrangeas, spicebush, grapes, rhododendron, Virginia creeper, elderberry, mountain laurel, poison ivy, and the small dogwoods.[2]

## Evaluation and Discussion

*Timber.*—This ecosystem occurs perhaps most commonly on good sites, but it also occurs on excellent and fair sites. For most situations, sawlogs and veneer logs should be the objectives of management, but for some fair-site stands small products may be the objective. The better the site, other factors being equal, the higher the level of management that is economically feasible.

Clearcutting offers the best opportunity to reproduce the highly desirable black cherry and white ash. However, because of the prevalence of sugar maple in this type, selection cutting is feasible when there is little opportunity to reproduce cherry and ash.

The birches, both sweet and yellow, present real problems in some areas where sufficient seed sources are not available to reproduce other more desirable species. The birches seed in and germinate prolifically, and sweet birch particularly grows very fast as a seedling. In spite of the high intrinsic value of birch logs, the birches are generally undesirable because in this area both species are heavily attacked by *Nectria* canker (*Hepting 1971*), and after they reach large sapling size their growth rates are very slow.

In determining sizes and ages of trees to grow to harvest time, rate of return information was used, as with the previously-described ecosystems, and the same considerations apply.

Overall, stumpage earning rates are favored by even-aged systems, by clearcutting larger areas, and by removing the trees at sizes which cease to return 6 percent (table 5).

*Water.*—Site conditions under northern hardwoods are variable in the central Appalachians and water behavior is hard to characterize. In general, soils are deeper and rainfall is least at lower elevations; soils are rockier and shallower and rainfall heavier at higher elevations. Perhaps northern hardwood sites are more water-productive and erosion-prone than in the oak ecosystem, less so than mixed hardwoods.

*Visual Appeal.*—Where the ecosystem occupies upper slopes, most northern hardwoods are highly visible. Northern hardwood forest cover is normally continuous over large areas. In some places, however, the northern hardwood type has been cleared primarily for grazing. In such areas, small clearcuts in adjacent forest stands may not have as severe an impact on visual appeal as in landscapes that have not been permanently or historically altered by man. As in other ecosystems, clearcutting in smaller patches with long rotations has less negative impact on visual appeal than clearcutting in larger patches with short rotations (table 5).

Uneven-aged management provides little opportunity to create visual landscape diversity. But the practice allows the characteristic landscape to be maintained. Where the characteristic landscape has not been altered through past land-use practices, selection cutting should be favored over clearcutting in order to preserve the visual landscape.

The practice "no commercial harvest" would not have an impact on existing visual quality unless cutting is done specifically to improve visual appeal.

*Wildlife.*—Northern hardwoods are generally less productive of wildlife than the other three hardwood ecosystems but are better than any of the three softwood ecosystems. This judgment applies to central Appalachia where black cherry and wild turkeys are particularly important but not to the beech-birch-maple associations farther north.

Black cherry-sugar maple is the most common subtype and is the focus of discussion here. Stands at higher elevations tend to be larger than those of other ecosystems except the oaks, at any elevation, and are good habitat for the wider-ranging wildlife species—notably deer, turkey, bear, and red fox. Cherry-maple can sustain good grouse populations, many non-game bird species, and, along with the spruce ecosystem, is suited locally to snowshoe hare. The type is not suited to the needs of gray squirrels; but fox squirrels may do well in northern hardwoods where mature stands with open understories border on favorable habitat such as cornfields and oak-hickory woods.

Where northern hardwoods occur at lower elevations, they usually are in small stands and their importance to wildlife depends

largely on their interspersion with non-forested land and other forest types.

In ranking the tree species to be favored for wildlife, black cherry is the strong front runner. Beech is a distant second but usually is preferable to the maples, birches, ash, basswood and magnolias, and to hemlock, white pine, and red spruce where they exceed 10 to 20 percent of the stand or are replacing cherry or beech.

Stand conditions to be favored for wildlife are those which increase or maintain black cherry and maintain beech. This is an impractical goal within individual small stands since cherry and beech have conflicting attributes, particularly in shade tolerance. Therefore, in most individual small stands, management should favor one species or the other. Preference should be given to cherry on more fertile sites such as coves surrounding spring seeps, and to beech on upper slopes and ridges. But favoring either one of these species does not imply attempting to totally exclude the other one or other mast producers such as ash and magnolia. Spruce, hemlock, and white pine generally should not be favored on ridges or slopes, but are most useful to wildlife around the mouths of intermittent streams and along permanent streams. There, the softwoods and associated rhododendron best serve as shelter for deer, grouse, snowshoe hare, bear, and other species.

Rotation lengths and proportions of stands in sawtimber-size trees, as with the other hardwood types, should be based on the wildlife preference objective—shorter rotations for deer and other edge species and longer rotations for turkeys and other interior species. But in either case, rotations of stands to favor cherry should be considerably shorter than rotations to favor beech.

Where black cherry or ash is featured, even-aged management is more effective than selection cutting and the aggregate acreage clearcut in any one or two years should be sufficient to disperse browsing by deer, rabbits and hares. Clearcuts as small as one-half acre are large enough for regenerating cherry. Proper sizes and distribution of clearcuts should be determined locally, and mostly in relation to expected browsing by deer. Thinning at age 30 or older should be designed to improve crown development of dominant and codominant black cherries primarily, but should retain small groups of aspen, a scattering of vigorous beech, and any dominant or codominant oaks present.

Where beech and other shade-tolerant species are to be favored, selection cutting is more appropriate than clearcutting. Marking should be done in the late summer or fall of a good beech mast year, should favor development of vigorous, full-crowned, mast-producing beeches, and should particularly discriminate against competing red and sugar maples, spruce, and hemlock. In some stands, group selection cutting can be arranged to favor beech plus some cherry in small patches which have been dominated by sugar maple or other shade tolerants except beech.

Where spruce or hemlock are to be favored—along runs and streams—no commercial cutting is usually the best alternative.

Spring seeps in northern hardwoods are of special and well-known value to turkeys and deer in winter and may require special attention. The conservative habitat management approach has been to exclude any cutting in and around spring seeps. Certainly, logging roads, skid trails, and slash should be kept out of the seeps. But their value to turkeys and deer is partly that they function as seed traps, catching mast which falls or rolls into them. This suggests that stands above and upslope from spring seeps should be managed for increased mast production. And this objective may indicate cutting to favor cherry—either clearcutting or thinning depending on the stand composition and age. Softwoods which shade spring seeps probably should be removed in nearly all cases where they retard snow-melt in the seeps (*William M. Healy, personal communication*).

## 4. WHITE PINE

### Description of the Ecosystem

White pine, a moderately-tolerant, long-lived, subclimax species, occurs throughout the Appalachians in pure stands and as a dominant species in association with hard-

woods, hemlock, and hard pines. It grows under a wide variety of site conditions. Best development is in moist stream bottoms, lower slopes, and protected coves. However, white pine is able to compete on upper slopes and ridge tops, and holds its own on the dry southerly exposure (*Ball 1949*). It is probably most typically associated with chestnut oak (*Soc. Am. Foresters 1967*). Doolittle (*1958*) found that white pine had a higher site index than nine of its most common associates on all lands except the very best, where yellow-poplar was superior.

White pine regeneration frequently follows major disturbance such as destructive logging, windfall, and fire, and is often the pioneer species on abandoned agricultural lands (*Cope 1932*). Although it has been classified as intermediate in tolerance, in the seedling stage it can survive and grow, if slowly, with as little as 20 percent of full sunlight (*U. S. Forest Service 1965*). However, in order to develop past the seedling-sapling stage, it must eventually be released from overtopping trees. Once it is established, it grows best in full sunlight (*U. S. Forest Service 1965*). Unless there is a major disturbance it is eventually displaced by more tolerant species.

Beneath pure or nearly pure stands of white pine, the shrub/vine layer is usually sparse and consists mostly of ericads—blueberries, huckleberries, azaleas, teaberry, and mountain laurel—plus scattered blackberries and greenbriers. Where there are more hardwoods, the understory associations are those typical of hardwood stands, but their growth is usually sparse due to shading by the pines.

## Evaluation and Discussion

*Timber.*—Because white pine requires ever-increasing exposure to sunlight as it gets older, it can best be managed by an even-aged system. However, young white pine trees are fairly tolerant and they can be started under canopy (*Wendel 1971*). This means that this species can be regenerated not only by clearcutting but also by shelterwood and small patch cutting. The seed tree method, while feasible, has little to recommend it (*Frothingham 1914*). The initial requirements are that the white pine reproduction be well started before the overstory is removed and that the overstory be harvested before the young white pine suffers seriously from shading. For the clearcutting method, if the final thinning in a stand is made about 10 years before the harvest cut, coincides with a good seed year, and is fairly heavy (somewhat similar to a first cut of a two-cut shelterwood); then a catch of pine reproduction can usually be expected. At that time, or shortly thereafter, the hardwood understory should be treated to favor the pine. At some later date, additional release work may be necessary to bring the young pine through to the time of the first commercial thinning.

Indications are that white pine competes successfully with hardwoods on sites of low quality for hardwood and, if favored by cultural measures, can be successfully managed as the predominant species. On such sites, much greater volumes of sawlogs can be produced by white pine than by hardwoods. As site quality improves, the difficulty and cost of favoring white pine over hardwoods increases and the growth advantage of white pine decreases. Based on present knowledge, it seems that conversion—or a heavy introduction of white pine into hardwood stands—may be profitable on areas of oak site index 45 to about 60 or a little lower. Where pine already exists, it should be favored on areas of oak site index up to about 65.

The product objective for white pine management should be sawlogs; small products may be obtained from thinnings and from tops and limbs. White pine is not an esteemed pulpwood species because of its low specific gravity. No rate of return information similar to that used in appraising hardwood stands is available for the pine. For a site of given quality, however, we can expect a higher stumpage interest rate to be earned as the size of clearcut openings is increased, at least between the sizes of openings used for comparison (table 6).

Most of the information on rotation ages and dbhs (shown in table 6) is based on unpublished data used by the Monongahela National Forest in managing white pine in pure stands and in stands mixed with hardwoods.

*Water.*—The discussions under floodplain hardwoods and mixed hardwoods apply to white pine on the best sites, while that under oaks is pertinent to white pine on poorer sites. Because most white pine likely will be grown on dry sites, the latter discussion seems applicable most often.

Rainfall interception and transpiration losses are higher in pure white pine than in hardwood stands. However, these differences are small in terms of precipitation in the central Appalachians, perhaps on the order of 2 to 4 inches per year. Nevertheless, it seems advisable to hold down the proportion of white pine (or any conifer) where water production is an important goal of forest management. Presumably, white pine (or any conifer) is as effective as hardwood for protecting the quality of headwater streams.

*Visual appeal.*—The white pine ecosystem provides visual enrichment to the central Appalachian landscape by presenting islands of diversity in the region's "sea of hardwoods".

The major criterion used to evaluate the visual impact of even-aged management was the size of the clearcut unit (table 6). As in other ecosystems, the visual appeal is reduced as clearcut size increases. Where white pine occurs mixed with hardwoods, clearcutting accompanied by hardwood control would be a desirable way to encourage white pine reproduction, and promote enrichment of the characteristic landscape. The negative visual impact of clearcutting is likely to be greater where white pine occurs in pure stands.

The effect of no commercial cutting would be much the same as in other ecosystems.

*Wildlife.*—Because this type occupies less than one percent of the forest acreage in central Appalachia, it is not important regionally for wildlife. Locally, however, white pine may occupy sites with high potential value as wildlife habitat. Mature stands that are large, uniform, and not interspersed with hardwoods have low value for wildlife. But stands at the other extreme—narrow, young or of various-sized trees, well interspersed with hardwoods —have at least moderate value through increasing the diversity of wildlife habitat.

Few kinds of wildlife are specifically associated with white pine. The wildlife species to be favored usually are those associated with adjacent forest types, typically the oak associations.

The tree species to favor are white pine in some stands as noted above, and the better mast-producing hardwoods. Some young pine and hemlock are desirable; they provide good cover for small birds during the nesting season and for grouse, rabbits, and sometimes quail. But as pine and hemlock mature they become less useful to wildlife than most hardwoods. White pine is notably unlikely to provide denning trees for squirrels, raccoons, owls, etc.

The stand conditions most favorable to wildlife are found where white pine stands are intermixed with hardwoods. Where pine—or hemlock—is to be retained, patches of nearly pure softwoods are preferable to scattered, isolated trees, or clusters of a few trees.

Silvicultural practices that favor the conversion of pine to shade-intolerant and moderately tolerant hardwoods are appropriate for wildlife purposes where pine stands are so large or so uniform that they appreciably reduce the diversity of the habitat. This conversion, under any silvicultural system, would require using cultural practices to favor the hardwoods and discriminate against the pine. However, converting all of a pine stand to hardwoods would rarely be good wildlife habitat management.

## 5. VIRGINIA PINE

### Description of the Ecosystem

In the central Appalachians the yellow pines are Virginia, pitch, and shortleaf. The discussion in this report is keyed to the short-lived, intolerant Virginia pine which is strictly a pioneer species. The principal associates of this species are: shortleaf pine, pitch pine, white pine, white oak, chestnut oak, scarlet oak, black oak, red oak, red maple, sourwood, and blackgum.

When farmlands are abandoned, or forest openings are created by windthrow or other major disturbance, pines often seed in on the

open lands. After 20 to 30 years, the pine stands are invaded by hardwoods which compete so strongly with the pine reproduction for light and moisture that few pine seedlings are able to survive (*Chapman 1948; Koslowski 1949; Kramer, Oosting, and Korstian 1952*). Thus mature stands of pine commonly contain a dense understory of young hardwoods. Harvesting of large pines and losses of pine trees by windthrow, insects, diseases, and fire create openings in the pine forest which are quickly occupied by the oaks and other hardwoods already present in the understory. In this way, the stands of pine gradually are transformed into oak-pine forests. As this process continues, the pine forest is ultimately replaced by oak-hickory forest. The change from forests predominately pine to an oak-pine mixture or to oak-hickory is hastened by heavier cutting of mature pine than of mature hardwood (*Wahlenberg 1949*), unless appropriate cultural methods are used to promote pine reproduction, survival and growth.

On the lowest quality sites where Virginia pine is found, forest succession from pure pine goes through a rotation of pine-hardwood before reverting to pure hardwood. The natural conversion process is shorter on the better sites, with pure hardwood often following nearly pure pine. (*Professor Kenneth L. Carvell, personal communication*).

The understory vegetation in Virginia pine stands may include grasses and sedges, but is commonly poor in herbaceous plants. The woody species vegetation is often moderately dense, more so than in spruce or most white pine associations. As in the oak types on drier sites, sassafras and flowering dogwood are key species among the large shrubs. Sumacs, serviceberry, redbud, eastern hophornbeam, and hawthorns are also common. The typical vines and small shrubs in approximate decreasing order are: brambles (blackberry, raspberry, dewberry), blueberries and huckleberries, greenbriers, grapes, mountain laurel, roses, deerberry, Virginia creeper, teaberry, poison ivy, St. John's wort, witch-hazel, and several others.[2]

## Evaluation and Discussion

*Timber.*—The objective of management for Virginia pine will be to grow pulpwood in as pure stands as possible; only even-aged systems will be considered because it is not feasible to grow this species in uneven-aged stands (*Slocum and Miller 1953*).

Mean annual growth culminates between 40 and 50 years of age, and stands older than 50 tend to become excessively open, thus permitting the development of a vigorous understory (*Slocum and Miller 1953*). For these reasons, clearcutting is recommended when the stands are 40 to 50 years old. This provides ample time for the production of pulpwood. Clearcutting should remove all merchantable stems of both pine and hardwoods.

To perpetuate Virginia pine, hardwood control will be necessary. Because Virginia pine is so intolerant, it is desirable to treat the hardwoods at or near the time of the regeneration cut. It is also desirable to use a chemical treatment to reduce sprout competition.

Thinning of commercial-sized Virginia pine is not recommended because of poor growth response (*Slocum and Miller 1953*) and the probable encouragement of hardwoods in the understory.

Virginia pine site indexes 50 and 60 correspond to oak site indexes 45 and 55 (*Doolittle 1958*). This fairly well covers the range of sites where we are likely to be growing Virginia pine in the central Appalachians.

The ratings in table 7 indicate that if the decision is made to grow Virginia pine on these sites, then returns on investment will be greater on the larger clearcut areas. They do not mean that Virginia pine stumpage will necessarily return a net profit under any of the situations listed. It may be that a grower dependent on net stumpage cannot afford to fight the hardwoods to the extent necessary to maintain Virginia pine, but an industrial owner supplying a mill with pulpwood may find it profitable to grow this species.

*Water.*—Virginia Pine occurs naturally on some of the driest sites in the central Appalachians, sites having virtually no potential for increased water production and with considerable erosion hazard. Virginia Pine also

seeds in or is planted on abandoned farmland. Here, soils may be deep, fine textured, and not stony but severely eroded in the recent past and likely to cause water quality problems. Traction may be poor for trucks, so unregulated use of logging roads in wet weather may rut them deeply and renew soil erosion. Extra care in road and logging practice is important to protect water quality. Two alternatives should be considered for watershed management:

(1) If the litter cover is adequate to protect the soil from erosion, let trees continue to grow to insure high quality of whatever water is produced naturally.

(2) If the litter cover and vegetation are sparse to the extent that soil is eroding, encourage establishment of cover to prevent further soil erosion.

This ecosystem ordinarily has little value if water production is an important goal of land management. On this or other dry and damaged sites, the manager will do well to look elsewhere for other than minimum water values.

*Visual Appeal.*—Although overall visual appeal of this ecosystem is low, Virginia pine stands do provide landscape diversity. But the ecosystem is often found on poor sites and trees seldom grow to large size in pure stands. Forest practices that encourage replacement of Virginia pine with hardwoods may have the most desirable long-run impact on visual appeal.

Because the ecosystem is not extensive and trees are usually small, clearcutting may not have the adverse visual impact it has in other forest types (table 7). Clearcutting with control of hardwood reproduction will retard visually desirable stand succession to hardwoods.

The visual appeal of Virginia pine stands may be improved through noncommercial cutting, but under most circumstances little can be done to enhance its visual quality.

*Wildlife.*—The Virginia pine ecosystem is substantially less important as wildlife habitat in central Appalachia than in the ridge and valley area to the east. The yellow pine and oak-pine forest types, of which the Virginia pine ecosystem is a part, occupy about 9 percent of central Appalachia forest land. Most of the stands are small and are growing on reverting farmland in Ohio, Kentucky, and western West Virginia. The pine forest types are generally less productive of wildlife than any of the moister site types except spruce, but they become more productive as oaks, hickories and other hardwoods replace the pines.

Rabbits, quail, many nongame birds, and a few other species find good habitat in very young stands of pine. But as the pines mature, self-prune, and shade out understory plants, they rapidly decline in value for nearly all wildlife species.

Accordingly, favoring hard pine will seldom provide good wildlife habitat. Exceptions occur where young pines are needed to furnish thickets of low cover, and comparable cover could not as easily be provided in thickets of greenbriers, grapes, brambles, hawthorns, or other species. Otherwise, oaks, hickories, and nearly all other hardwoods are preferable to pines. This is particularly true where the landowner's objectives favor the forest game species such as gray squirrels and turkeys over species such as rabbits and quail.

The stand conditions to favor for forest wildlife usually are those which accelerate replacing some of the pines with oaks, hickories, and associated hardwoods. As this change occurs, the stands will first improve for edge species (deer and grouse for example), will pass through an awkward pole stage, of marginal quality for either edge or interior species, and then will succeed to the mast production stage more favorable to turkeys and squirrels but still fair as deer and grouse range. This conversion process will take about 40 years. During that time, a choice can be made on proportions of the stands to be in the various stand-size classes and then the stands can be planned for management under the options suggested for the oak types.

Because clearcutting accompanied by control of hardwood regeneration favors pines, it would seldom improve wildlife habitat, except for a few years and for a few species of wildlife. No commercial cutting—except for removal of pines—would usually be a better

choice. But where advanced regeneration of hardwoods is abundant and thrifty, clearcutting most of the pines would accelerate conversion from pine to hardwoods.

## 6. RED SPRUCE

### Description of the Ecosystem

Red spruce attained its maximum development in the Appalachians (*Korstian 1937*). Almost all the red spruce in the central Appalachians is in West Virginia. Core (*1966*) estimated that the red spruce type originally occupied 469,000 acres in the mountains of northern and eastern West Virginia at elevations above 3,200 feet. The acreage of this type was drastically reduced by the intense fires that followed the original clearcuttings around the turn of the century.

In the spruce areas, the climate is cool and humid with annual rainfall in the neighborhood of 60 inches.

Red spruce grows in association with hemlock, red and sugar maple, yellow birch, pin cherry, beech, and black cherry, but it may grow in almost pure stands. Part of the national forest land formerly occupied by red spruce has been planted to Norway spruce in pure planations.

Because the wildfires that reduced the acreage of spruce also reduced the depth of the largely-organic soil in which most of the spruce formerly grew, site quality, too, was reduced. The relatively small acreage of spruce in pure or nearly pure stands generally occupies areas of shallow rocky soils where site quality is fair to poor. Most of the spruce found on better sites occurs as scattered groups or as individual trees in the northern hardwood ecosystem. By definition, the red spruce type includes stands composed 50 percent or more of red spruce, but because in most situations the type includes stands composed of up to 50 percent hardwood stems, the type can logically be considered a spruce-hardwood complex.

The understory beneath closed stands of spruce is usually dominated by mosses, lichens, and club-mosses with ocassional wood sorrel, trillium, and teabury plants. In openings and along edges or beneath open mature stands, rhododendron, mountain ash, and wild raisin are key shrubs. They may be associated with high-bush cranberry, mountain holly, mountain laurel, speckled alder, pin cherry, serviceberry, brambles, blueberries, and huckleberries. Where the type intergrades with northern hardwoods, the understory is usually better developed and becomes more like that of the cherry-maple type.

### Evaluation and Discussion

*Timber.*—Because the spruce ecosystem occurs in the "high country" where recreation is increasingly important, and because it offers pleasing scenic contrasts in this predominately hardwood region, in most locations it is probably of greater value for esthetics than for wood. Although this type covers only a very small area, its inclusion in this paper is justified by its strategic location and uniqueness from a scenic standpoint.

Because red spruce is shade tolerant, it is amenable to all the silvicultural systems except seed-tree harvesting (*Hart 1963; Westveld 1953*); the species is so shallow-rooted that seed trees tend to blow down.

Clearcutting is the best harvesting system for even-aged stands that are mature or overmature and on sites where windthrow is a problem (*Frank 1968; Hart 1963; Westveld 1953*). It yields the heaviest cut and costs the least per unit of volume removed. Intermediate operations may be practicable in some stands growing on better sites.

Selection cutting secures regeneration and is particularly applicable where site protection, esthetic values and recreational use are dependent on a healthy, continuous forest cover. However, care should be taken on exposed areas not to open up the stand heavily enough to risk windthrow.

The shelterwood system in which the overstory is removed in two or more cuttings is applicable to most stands except those that are on shallow soils on very exposed sites.

Because no silvicultural research has been done on red spruce in the Appalachians, the ratings in table 8 are based on generalized practices. First, we recommend that no com-

mercial cuttings be applied on poor sites. Then, we recommend that on the fair and good sites the objective be to grow large sawtimber trees—the dbhs shown are relative rather than absolute. The ratings simply reflect the fact that we can expect greater returns from our timber investment on large clearcuts than on small clearcuts, and we can expect a higher stumpage return from clearcutting and even-aged management than we can for selection cutting and uneven-aged management.

*Water.*—The spruce zone is the only part of central Appalachia where snow management principles developed in the west could be applied to increase water yields. However, there is little reason to do so because the spruce forest is too limited in extent and too remote from water-short large cities to render such management useful.

Today, wildfire rarely burns the spruce type but severe water quality problems may result if it does. With organic matter burned away, infiltration of water into the rocky subsoil may be so reduced that subsequent overland flow will wash away sparse soil and tree nutrients. Thus, burning in red spruce poses the dual hydrologic problem of reduced capacity to store rain and snowmelt in addition to considerable stream pollution by ash and mud.

*Visual Appeal*—The spruce hardwood ecosystem, although limited in extent, provides variety in the central Appalachian landscape. Because red spruce is shade-tolerant and occurs in pure and mixed, even- and uneven-aged stands, it is difficult to generalize about the visual impact of timber harvesting methods. Selection cutting in uneven-aged stands would have little impact on visual appeal (table 8).

Where stands are even-aged, clearcutting would maintain the familiar landscape in the long-run, but would have a negative immediate effect. Large clearcuts would have a negative impact on visual appeal, but small and medium sized clearcuts may improve visual appeal in even-aged stands — particularly when man-made openings predominate in the characteristic landscape or where opening scenic vistas will enhance panoramic views. Selection or other partial cutting practices will not significantly influence visual appeal.

"No commercial cutting" can be used to improve visual appeal either by maintaining pristine conditions or by removal of unsightly trees in appropriate situations.

*Wildlife.*—The spruce ecosystem might rank with the least productive ecosystems for wildlife because it accommodates few species, and as the least important because the type accounts for only one one-thousandth of the forested acreage. But this type has a special appeal because it is scarce—less than 10 percent of the original acreage remains. And natural spruce systems include wildlife that either are not regularly found elsewhere in central Appalachia or are scarce elsewhere during spring and summer. These "northern" species include snowshoe hare, but are mostly wood warblers and other songbirds, rodents, salamanders and the like—not game animals.

Several game species such as bear, grouse, and deer are adapted to using at least the edges of mature spruce stands but are not necessarily attracted by them. Generally, game habitat is improved when aspen, northern hardwoods, or shrub cover replaces some of the mature spruce. Accordingly, large stands of red spruce should seldom be favored over hardwood-spruce mixtures where the objective is to improve habitat for game animals except snowshoe hare. Black cherry, beech, viburnums, and most other deciduous plants are preferable to spruce.

Where deer, grouse, and the like are considered less important than the nongame species that are more or less uniquely associated with the type, red spruce should be more favored over shrubs and hardwood trees. In general, nongame species and snowshoe hare would benefit from more spruce, either in a mosaic of small even-aged stands of several age classes or in old-growth stands that include scattered openings and patches of mixed spruce-hardwood growth.

The conditions to favor for game animals except hares are those suggested for spruce and hemlock in the northern hardwood discussion, namely, retention of the softwoods along streams where spruce usually has a well

developed understory. Elsewhere spruce can be retained in small patches but scattered single trees or small, isolated clumps of a few spruce might better be replaced by hardwoods or shrubs. Wind-exposed sites are particularly suitable for replacement of closed-canopy spruce stands by shrubs mixed with shrubby spruce and hardwood trees and herbaceous cover.

Where spruce is managed for improvement of deer and grouse habitat, even-aged management based on clearcutting narrow patches of moderate size, say about 5 acres, may be the best of the timber management options. Spruce regeneration can be controlled, if need be, during the harvest cut or subsequent weedings. Smaller and more numerous clearcuts would be better for hares and the non-game animals, nearly all of which have smaller home ranges than the game animals. Patch cutting in ½ to 1 acre patches can be used to furnish interspersion, and may be preferable in spruce stands that are somewhat uneven-aged at the start.

## 7. FLOODPLAIN HARDWOODS

### Description of the Ecosystem

This is a composite of pioneer to subclimax forest types which can be described more readily in landscape terms than by plant species composition. The ecosystem occurs mostly in narrow bands or "oxbows" along low-gradient streams, particularly the Ohio River and the lower reaches of its tributaries. Landforms within the bands or oxbows have been categorized as water margin, backwater pocket, bar, cutbank, floodplain proper, and floodplain depression *(Lindsey et al. 1961)*.

Soils supporting floodplain hardwoods generally are finer textured, wetter, more fertile, higher in organic content, and more variable within small areas than upland forest soils. The better-drained soils have mostly been cleared for agricultural and other uses. Floodplain hardwoods grow mostly on poorly drained soils such as the Atkins, Lindside, Melvin, and Senecaville series *(Ellyson, Fonner, and Kunkle 1970; Keith O. Schmude, personal communication)*.

Plant succession may be more variable in bottomland types than in most upland types, due to flooding and other disturbances. But the normal progression of stages is: annual grass-forb, perennial grass-sedge, perennial forb-sapling, sapling-woodland forb, to subclimax forests; i.e. river birch-sycamore, silver maple-elm, or equivalent *(Lindsey et al. 1961)*.

The floodplain hardwoods group includes three types defined by the Society of American Foresters *(1967)*: river birch-sycamore (61); silver maple-American elm (62); and cottonwood (63). In forest survey reports by the US Forest Service, such types are combined within the major forest type elm-ash-maple.

Tree species as given by Core *(1966)* are: *Widespread*: black willow, sycamore, American elm, sweet gum, silver maple, river birch, red maple, boxelder, green ash, cottonwood, shell-bark hickory; *Local*: Kentucky coffee-tree, honey-locust, hackberry, paulonia, catalpa, pin oak and several "white" oak species, and others. On the higher, better drained bottoms the highly-valuable black walnut is often found.

Core *(1966)* lists the following shrubs and woody vines as commonly found in the understory of this ecosystem: sandbar willow, silky willow, grapes, trumpet vine, Virginia creeper, poison ivy, alder, ninebark, meadowsweet, winterberry, bladdernut, wahoo, kinnikinnick, buttonbush, black elderberry, greenbriers, blackberries, swamp rose, bittersweet, moonseed, virgin's bower, and others.

### Evaluation and Discussion

*Timber.*—Floodplain hardwoods are substantially less important for commercial timber production than the other hardwood types in central Appalachia. However, locally they are a source of both pulpwood and sawlogs. Timber growth is rapid and some of the species—among which are cottonwood, sycamore and silver maple—are quite valuable.

In many situations, the ecosystem—in most instances forming only a ribbon along the streams—is not large enough to be managed as a unit but is best handled as part of the contiguous forest ecosystem lying above it.

However, in the larger river valleys, stands are often large enough to justify applying a separate management system.

The key species in this type—cottonwood and sycamore—are highly intolerant and can be reproduced only by clearcutting. However, the vegetative response on cut-over sites is heavy to Johnson grass, other weeds, brush, and box elder. In the absence of early intermediate treatments, the lush growth of undesirable plants often prevents the establishment of a good stand of timber. So while clearcutting is called for, so is early precommercial work if intensive forestry is to be practiced. In general, the feeling is that the larger the clearcut, the more the profits from the operation.

In areas where forestry will be practiced in the future, it is probable that the experience and research developed in the floodplains to the south has real pertinence, and some foresters strongly recommend clearcutting, site preparation, planting cottonwood, and some cultivation, as is practiced in southern bottomlands. A little planting has been done, mostly silver maple, cottonwood, and sycamore, but this is not a prevalent practice.

It is a consensus among foresters in the area that selection cutting is impractical. However, perhaps in woodlots the system could be justified—with very light cutting to prevent the establishment of a brushy understory.

Insufficient information on growth rates and other characteristics of these stands prevents the definition of even-aged relationships in terms of tree size and stand age (table 9). For the same reason, it was not possible to present tree-size data for alternate choices in the selection system.

Growing black walnut with intensive culture is a possibility for the higher, better drained bottoms.

Many, if not most, floodplain hardwood stands are used for livestock grazing—a practice that conflicts with some other uses.

Much of this land is so valuable for farming, particularly growing corn, that land clearing is a continuous threat to the growing of wood crops.

*Water.*—This ecosystem is the most water-productive in the region, the only one where ground water is both common and easily accessible. Water tables are close to the land surface along streams, at the mouths of coves, and at the base of slopes. Floodplains are high-value sites for recreation and wildlife, so plans to manage these areas intensively for water must be conditioned by other resource needs. But if water need is paramount, then forest cutting should provide high yields, although studies on which this claim is based were done in the American west. In addition, proximity to cities and farms assures transport at minimum cost of water so produced.

There are, however, serious hazards to quality in managing this ecosystem for water. It is a floodplain formation on which periodic overflow is commonplace. Roads inevitably will alter the natural drainage and expose some soils to erosion. Muddy ditch water also is inevitable and has no place to drain except into streams. High recreation use contributes all sorts of pollutants, also with no place to drain except into streams. In addition, eroded soil and other pollutants of upstream origin are carried into the floodplain. Sensible regulation of all uses (e.g., zoning, policing, and control of access) probably provides the best water resource protection.

*Visual Appeal.*—Floodplain hardwoods, by their association with stream bottoms, have the highest potential for socially-oriented forest uses of any of the central Appalachian ecosystems.

The ecosystem is usually associated with farming activities, urbanization, and transportation routes. The characteristic landscape, therefore, has been strongly influenced by man's activity. Because of this landscape variability, the negative visual impact of clearcutting is not as great as in more steep terrain, or where continuous forest cover forms the major landscape character.

Selection cutting would have little impact on visual appeal in most situations. As with other ecosystems, "no commercial cutting" either has no effect or can be used to enhance visual appeal through judicious selective cutting.

*Wildlife.*—This ecosystem and the adjacent woodlands were once the most productive of

all wildlife habitats. Now, the remnants of floodplain hardwoods are regionally unimportant in wildlife production, but locally their value is high and is subject to changing appraisals as public concern for environmental quality grows.

Floodplain hardwood sites are suited for more wildlife species than any other type. Floodplains accommodate most upland species plus wetlands-associated animals such as wading and shore birds, ducks, several furbearers, and frogs. But the shape, size, and ownership pattern among floodplain hardwood stands imply that many are as well or better suited to management for trapping and non-consumptive uses of wildlife as for hunting.

Choices among tree species to be favored for wildlife are usually narrow, due to microsite conditions. Generally, the oaks, hickories, hackberry and other hard-mast producers should be favored on better drained sites. Most of the other species have moderate value for wildlife but cottonwood and sycamore may be the least useful.

The stand conditions most favorable to variety among wildlife species include mixtures of many different tree species, scattered openings in the overstory, and a well-developed midstory and understory. Openings made near streams or trails may be appropriate for nesting habitat of songbirds, berry production, and so on.

Stands should include trees suitable for tree denning or nesting species such as squirrels, raccoons, owls, wood ducks, and hooded mergansers. Livestock foraging generally should not be permitted, except where the understory is too dense for some desirable habitat condition such as the openness preferred by woodcock.

Most stands are too small or narrow for conventional timber management practices. Where there is a need to open up the canopy to favor the understory or to release the more desirable species of trees, such as oaks or hickories, girdling or selective removal of individual stems can be used.

In larger stands, clearcutting of small patches may be used to diversify wildlife habitat, particularly where sycamore or cottonwood predominate.

## Application Examples

The following examples illustrate how the information in this report can be used as an aid to evaluating forest management alternatives for specific situations. Theoretical situations were set up within specified ecosystems with indicated priorities among the four resources: timber, water, visual appeal, and wildlife.

It should be emphasized that the material contained in this report is intended to serve only as a guide. Actual decisions can only be made by owners or managers who specify their own sets of objectives.

*Case I. Appalachian Mixed Hardwoods. Excellent site.*—This is a large back-country hollow, not readily visible to the travelling public. The owner's first objective is timber production, but he has considerable side interest in improving deer habitat. The only watershed consideration is protection of water quality. The importance of visual appeal is minimal; sight-seers don't get into the area, and recreation is not an important management concern.

From the standpoint of the two management objectives—timber and deer habitat—even-aged management with clearcutting produces better effects than any other forest practice (table 4). While the optimum size clearcut unit for deer habitat is 5 acres, the optimum sized clearcut unit for timber production is 25 acres or more. The manager has narrowed his alternatives and must identify the tradeoff values between his two objectives —timber and deer habitat.

Based on the above considerations, the decision is made to practice even-aged management with clearcut units ranging between 5 and 25 acres. Rotation ages will be short (about 65 years) to favor both timber returns and deer habitat.

Where markets permit, periodic thinnings from below will be made. On occasion it may be necessary to reduce the tolerant understory before clearcutting to provide opportunity for post-harvest development of the desirable intolerants.

Design, construction, and after-logging care

of the logging road system will follow established guidelines to minimize damage to water quality.

*Case II. Oak ecosystem. Fair site.*—This area covers a long south slope, and a large part of it is visible from a heavily-travelled highway. Both game management—largely for squirrels and turkeys—and visual appeal are important owner objectives. Timber production also is important, but to a lesser extent. No need exists for increased water yield, but it is important to protect water quality.

To maintain the mast-producing oak, even-aged management is necessary, but to provide the best habitat conditions for squirrels and turkeys (interior species), clearcut openings should be kept small (table 3). Another reason for keeping clearcut openings small is to guard against adverse visual impact on the highway users. But the efficient production of timber is penalized when opening size is limited to less than 5 acres. The length of rotation also affects the desirability of the practice: longer rotations with larger trees will enhance visual appeal and produce better conditions (more mast) for squirrels and turkey, but they lower rates of return from timber.

Balancing the diverse pressures, the owner decides to practice even-aged management with 5-acre clearcuts on a rotation of 115 years. This plan favors conditions for squirrels and turkey, is fair from the standpoint of visual impact and gives a low return from stumpage (table 3).

Within the framework of this plan, other practices can be implemented to enhance or protect desired resource values. If markets permit periodic thinning, mast production and possibly stumpage returns can be increased. Den trees can be left for squirrels. Road patterns and clearcut units can be laid out to minimize their impact on visual appeal. And the use of erosion control measures on the logging road system will protect water quality.

*Case III. Red Spruce. Fair site.*—The forest property is in the high country and is made up of middle-aged, mixed spruce and scrubby hardwoods. It is readily accessible and heavily used for hiking and camping. Moreover, the area is a favorite place for bird watchers who find here many species of warblers. Streams provide fishing for stocked trout.

The owner's major management objectives are to enhance visual appeal and wildlife values. Timber production is not important.

Based on his use priorities, the manager decides to apply the forest practice "no commercial cutting" (table 8). Although small clearcut units would be of some value in producing wildlife habitat, the owner feels that these gains in wildlife production would be more than offset by resulting deterioration of visual appeal. The practice adopted does not preclude all cutting. Trees will be removed for trails, scenic vistas, and improved access, as well as to reduce hazards and release particularly attractive vegetation specimens. Erosion-reducing measures will be carried out in access trails and roads to maintain water quality.

As the stand matures (120+ years old) under the "no commercial cutting" management practice, it may be necessary to conduct limited timber harvesting—accompanied by cultural measures to favor spruce—to perpetuate the spruce ecosystem.

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# Appendix

## TIMBER-RELATED RESOURCES OF CENTRAL APPALACHIA

From data in forest survey files of the Northeastern Forest Experiment Station and in USDA Forest Service Resource Bulletins NE-9, Kentucky (1968); NE-7, Maryland (1967); NE-14, Ohio Hill Country (1969); NE-8, Pennsylvania (1968); SE-8, Virginia (1966); and NE-2, West Virginia (1964).

Table 10.—*Area in Central Appalachia, by land classes and states*

[Thousands of acres]

| State and survey unit | Total land area | Nonforest land area | Forest land area | | |
|---|---|---|---|---|---|
| | | | Total | Non-commercial | Commercial |
| KENTUCKY | | | | | |
| No. Cumberland | 2,494.1 | 624.7 | 1,869.4 | 11.6 | 1,857.8 |
| Eastern | 2,135.7 | 317.2 | 1,818.5 | 23.0 | 1,795.5 |
| So. Cumberland | 2,774.4 | 553.8 | 2,220.6 | 19.9 | 2,200.7 |
| State total | 7,404.2 | 1,495.7 | 5,908.5 | 54.5 | 5,854.0 |
| MARYLAND | | | | | |
| Garrett Co. | 423.7 | 131.5 | 292.2 | 2.3 | 289.9 |
| OHIO | | | | | |
| East-central | 3,417.7 | 1,830.0 | 1,587.7 | 20.8 | 1,566.9 |
| Southeastern | 2,074.2 | 792.7 | 1,281.5 | 8.8 | 1,272.7 |
| Southcentral, part | 2,349.1 | 1,053.8 | 1,295.3 | 2.6 | 1,292.7 |
| State total | 7,841.0 | 3,676.5 | 4,164.5 | 32.2 | 4,132.3 |
| PENNSYLVANIA | | | | | |
| Western, part | 4,013.3 | 2,138.5 | 1,874.8 | 27.1 | 1,847.7 |
| Southwestern, part | 1,647.0 | 602.5 | 1,044.5 | 12.3 | 1,032.2 |
| State total | 5,660.3 | 2,741.0 | 2,919.3 | 39.4 | 2,879.9 |
| VIRGINIA | | | | | |
| S. Mountain, part | 1,394.5 | 385.9 | 1,008.6 | 19.0 | 989.6 |
| WEST VIRGINIA | | | | | |
| Northwestern | 4,454.0 | 1,364.0 | 3,090.0 | 6.0 | 3,084.0 |
| Southern, part | 4,723.9 | 739.2 | 3,984.7 | 11.3 | 3,973.4 |
| Northeastern, part | 3,096.3 | 937.0 | 2,159.3 | 29.3 | 2,130.0 |
| State total | 12,274.2 | 3,040.2 | 9,234.0 | 46.6 | 9,187.4 |
| Regional total | 34,997.9 | 11,470.8 | 23,527.1 | 194.0 | 23,333.1 |

Table 11.—*Area of commercial forest land in central Appalachia, by ownership classes and states*

[Thousands of acres]

| State and survey unit | Public | | Private | | | Total |
|---|---|---|---|---|---|---|
| | National forest | Other | Forest industry | Farmer | Miscellaneous | |
| KENTUCKY | | | | | | |
| No. Cumberland | 109.2 | 0.8 | 5.2 | 1,246.3 | 496.3 | 1,857.8 |
| Eastern | 1.0 | 39.5 | 85.8 | 613.8 | 1,055.4 | 1,795.5 |
| So. Cumberland | 306.0 | 19.4 | 61.4 | 1,454.8 | 359.1 | 2,200.7 |
| State total | 416.2 | 59.7 | 152.4 | 3,314.9 | 1,910.8 | 5,854.0 |
| MARYLAND | | | | | | |
| Garrett Co. | — | 76.0 | [a] | 74.6 | 139.3 | 289.9 |
| OHIO | | | | | | |
| East-central | 4.3 | 32.2 | 12.1 | 587.6 | 930.7 | 1,566.9 |
| Southeastern | 59.0 | 45.5 | 44.9 | 514.9 | 608.4 | 1,272.7 |
| Southcentral, part | 49.0 | 112.2 | 58.2 | 457.2 | 616.1 | 1,292.7 |
| State total | 112.3 | 189.9 | 115.2 | 1,559.7 | 2,155.2 | 4,132.3 |
| PENNSYLVANIA | | | | | | |
| Western, part | — | 48.2 | 2.9 | 541.2 | 1,255.4 | 1,847.7 |
| Southwestern, part | — | 122.8 | 18.7 | 296.4 | 594.3 | 1,032.2 |
| State total | — | 171.0 | 21.6 | 837.6 | 1,849.7 | 2,879.9 |
| VIRGINIA | | | | | | |
| S. Mountain, part | 44.8 | 13.7 | 136.5 | 229.1 | 565.5 | 989.6 |
| WEST VIRGINIA | | | | | | |
| Northwestern | — | 45.0 | 77.0 | 1,124.0 | 1,838.0 | 3,084.0 |
| Southern, part | 119.5 | 43.0 | 168.7 | 547.9 | 3,094.3 | 3,973.4 |
| Northeastern, part | 314.7 | 21.1 | 149.8 | 609.5 | 1,034.9 | 2,130.0 |
| State total | 434.2 | 109.1 | 395.5 | 2,281.4 | 5,967.2 | 9,187.4 |
| Regional total | 1,007.5 | 619.4 | 821.2 | 8,297.3 | 12,587.7 | 23,333.1 |

[a]Combined with miscellaneous private to avoid disclosing individual industry ownership.

Table 12.—*Area of commercial forest land in central Appalachia, by stand-size classes and states*

[Thousands of acres]

| State and survey unit | Sawtimber stands | Poletimber stands | Seedling-sapling stands | Nonstocked areas | Total |
|---|---|---|---|---|---|
| KENTUCKY | | | | | |
| No. Cumberland | 847.5 | 503.9 | 505.5 | 0.9 | 1,857.8 |
| Eastern | 1,074.8 | 256.8 | 459.3 | 4.6 | 1,795.5 |
| So. Cumberland | 1,141.6 | 508.7 | 534.4 | 16.0 | 2,200.7 |
| State total | 3,063.9 | 1,269.4 | 1,499.2 | 21.5 | 5,854.0 |
| MARYLAND | | | | | |
| Garrett Co. | 121.7 | 115.6 | 46.1 | 6.5 | 289.9 |
| OHIO | | | | | |
| East-central | 367.3 | 179.5 | 966.8 | 53.3 | 1,566.9 |
| Southeastern, part | 397.2 | 153.6 | 680.7 | 41.2 | 1,272.7 |
| Southcentral, part | 420.1 | 191.7 | 661.4 | 19.5 | 1,292.7 |
| State total | 1,184.6 | 524.8 | 2,308.9 | 114.0 | 4,132.3 |
| PENNSYLVANIA | | | | | |
| Western, part | 926.7 | 322.0 | 484.0 | 115.0 | 1,847.7 |
| Southwestern, part | 524.6 | 287.9 | 190.9 | 28.8 | 1,032.2 |
| State total | 1,451.3 | 609.9 | 674.9 | 143.8 | 2,879.9 |
| VIRGINIA | | | | | |
| S. Mountain, part[a] | 323.6 | 368.9 | 291.1 | 6.0 | 989.6 |
| WEST VIRGINIA | | | | | |
| Northwestern | 1,439.0 | 713.0 | 750.0 | 182.0 | 3,084.0 |
| Southern, part | 2,023.7 | 1,096.5 | 853.2 | — | 3,973.4 |
| Northeastern, part | 1,027.6 | 626.4 | 445.5 | 30.5 | 2,130.0 |
| State total | 4,490.3 | 2,435.9 | 2,048.7 | 212.5 | 9,187.4 |
| Regional total | 10,635.4 | 5,324.5 | 6,868.9 | 504.3 | 23,333.1 |

[a]Estimates are based on the statewide percentages since county and unit data were not available.

Table 13.—*Area of commercial forest land in central Appalachia, by forest types and states*

[Thousands of acres]

| State and survey unit | White pine | Spruce | Pitch-shortleaf-Virginia pine | Oak-pine | Oak-hickory | Oak-gum | Elm-Ash-Cottonwood | Maple-beech-birch | Aspen | Total, all types |
|---|---|---|---|---|---|---|---|---|---|---|
| KENTUCKY | | | | | | | | | | |
| No. Cumberland | — | — | 99.5 | 151.2 | 1,541.5 | — | 22.1 | 43.5 | — | 1,857.8 |
| Eastern | — | — | 30.4 | 43.1 | 1,610.4 | — | 7.3 | 104.3 | — | 1,795.5 |
| So. Cumberland | — | — | 132.8 | 287.9 | 1,676.1 | — | 54.7 | 49.2 | — | 2,200.7 |
| State total | — | — | 262.7 | 482.2 | 4,828.0 | — | 84.1 | 197.0 | — | 5.854.0 |
| MARYLAND | | | | | | | | | | |
| Garrett Co. | 23.3 | — | — | 14.5 | 227.2 | — | 4.9 | 20.0 | — | 289.9 |
| OHIO | | | | | | | | | | |
| East-central | 37.5 | — | 11.7 | 112.9 | 600.2 | 4.3 | 457.7 | 303.3 | 39.3 | 1,566.9 |
| Southeastern | 6.1 | — | 57.0 | 74.7 | 768.2 | 13.2 | 149.4 | 197.2 | 6.9 | 1,272.7 |
| Southcentral, part | 7.5 | — | 99.5 | 91.1 | 768.1 | 6.6 | 165.7 | 148.5 | 5.7 | 1,292.7 |
| State total | 51.1 | — | 168.2 | 278.7 | 2,136.5 | 24.1 | 772.8 | 649.0 | 51.9 | 4,132.3 |
| PENNSYLVANIA | | | | | | | | | | |
| Western, part | 86.5 | — | 13.3 | — | 522.0 | 37.9 | 428.8 | 350.3 | 408.9 | 1,847.7 |
| Southwestern, part | 23.3 | — | 14.9 | 7.1 | 558.6 | 48.9 | 92.7 | 231.2 | 55.5 | 1,032.2 |
| State total | 109.8 | — | 28.2 | 7.1 | 1,080.6 | 86.8 | 521.5 | 581.5 | 464.4 | 2,879.9 |
| VIRGINIA | | | | | | | | | | |
| S. Mountain, part | 11.7 | — | 46.6 | 212.1 | 689.1 | — | 1.6 | 28.5 | — | 989.6 |
| WEST VIRGINIA | | | | | | | | | | |
| Northwestern | 15.0 | — | 299.0 | 42.0 | 1,916.0 | 14.0 | 299.0 | 499.0 | — | 3,084.0 |
| Southern, part | 41.2 | 3.8 | 77.5 | 27.1 | 2,763.6 | 54.2 | 236.8 | 769.2 | — | 3,973.4 |
| Northeastern, part | 6.8 | 16.9 | 106.2 | 25.2 | 1,328.8 | 43.6 | 89.0 | 513.5 | — | 2,130.0 |
| State total | 63.0 | 20.7 | 482.7 | 94.3 | 6,008.4 | 111.8 | 624.8 | 1,781.7 | — | 9,187.4 |
| Regional total | 258.9[a] | 20.7 | 988.4 | 1,088.9 | 14,969.8 | 222.7 | 2,009.7 | 3,257.7 | 516.3 | 23,333.1 |

[a]Includes a small acreage in spruce plantations.



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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

# MUNICIPAL WATERSHED MANAGEMENT

## Symposium Proceedings



*Planned and Presented by*

U.S. Department of Agriculture, Forest Service
Institute for Research on Land and Water Resources,
The Pennsylvania State University
New Hampshire Water Resources Research Center
University of New Hampshire

*In Conjunction with*

The Pinchot Institute for Environmental
Forestry Research

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1975

FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

## FOREWORD

SINCE THE BEGINNING of time, forests and streamflow have been interrelated. Although this relationship has not always been completely understood, it was accepted about the turn of the century that forests generally exert a beneficial influence on streamflow. This concept was based on the fact that forests provide a protective cover on the soil surface, thereby allowing rainfall to infiltrate into the soil rather than flowing over the surface and eroding the soil. History has provided sufficient evidence that, where man has carelessly removed the forest and has denuded the land, devastation occurred. Fertile top soil was lost by erosion; springs ceased to flow; streams dried up; and damaging floods occurred. In some instances, the total result was the demise of the civilization.

Increasing population and improved technology have placed new values on the forest and water resources, particularly in highly urbanized regions. For instance, in the densely populated Northeast, the primary source of most of the surface water is streamflow from forested watersheds. In this area there are more than 2 million acres of land under the control of municipalities, private water companies, and state and federal agencies for management as either water-source areas or protection lands for municipal water supplies. Continuing urbanization has increased water demands and has necessitated that these watersheds be managed for maximum water production, while at the same time there are mounting public pressures to utilize these areas for recreation.

During the past 30 years, forest-watershed-management research has produced a wealth of information about water-yield augmentation and water-quality protection. The purpose of this Symposium was to bring together some of the research and management information that would be useful to municipal watershed administrators in formulating land-management policies.

Financial support for the Symposium was provided by the Institute for Research on Land and Water Resources and the School of Forest Resources, The Pennsylvania State University; New Hampshire Water Resources Research Center, University of New Hampshire; and The Pinchot Institute for Environmental Forestry Research, Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture. Partial support was also provided by the Office of Water Resources Research, U.S. Department of Interior, as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

The program was conducted in cooperation with the American Water Works Association, the New England Water Works Association, and the Pennsylvania Department of Environmental Resources.

---

*A report on the Symposium held 11-12 September 1973 at The Pennsylvania State University, University Park, Pennsylvania, and 19-20 September 1973 at The University of New Hampshire, Durham, New Hampshire.*

# MUNICIPAL WATERSHED MANAGEMENT

## Symposium Proceedings

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The Symposium was organized and conducted as one of the activities of the Working Group on Municipal Watershed Management of the Pinchot Institute Consortium for Environmental Forestry Studies. Members of the planning committee were:

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# EFFECTS OF MANAGEMENT PRACTICES ON WATER QUALITY AND QUANTITY: COWEETA HYDROLOGIC LABORATORY, NORTH CAROLINA

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*ABSTRACT.* Results from nearly 40 years of watershed experiments at Coweeta are summarized. An equation is presented to predict the annual increase in streamflow from the percent basal area cut and from the theoretical extra-terrestrial radiation load for the watershed. Timing of the increased flow from watershed experiments depends on the magnitude of the increase, but results consistently show that much of the increase appears in the low-flow season. Two watershed experiments indicate that conversion of hardwoods to white pine substantially reduces monthly and annual streamflow. Conversion of a hardwood-covered watershed to grass produces up to 5.8 inches of increased flow per year. Although some increase in nutrient export occurs from forest cuttings and species conversions, the increase is well within drinking-water standards.

SINCE THE 4,000-acre Coweeta Experimental Forest was established in 1933, the research effort there has been to determine the effects of man's use of the forest on the quality, quantity, and timing of streamflow. About 20 controlled watershed experiments and many plot and laboratory studies have taken place. The results provide useful information to the municipal watershed manager interested in improving water supplies. These results, when combined with those from the other sites in the Appalachian Highlands, provide the most complete and detailed information available anywhere on the response of streams to management by man.

## DESCRIPTION OF THE BASIN

### *Climate*

The marine climate of the basin and surrounding area is characterized by cool summers and mild winters. Maritime tropical air masses which develop over the Gulf of Mexico, Caribbean Sea, and Atlantic Ocean are the primary source of precipitation. Rainfall occurs from frontal, convection, and orographic and occasionally from cyclonic storms.

Precipitation for the basin averages 80 inches annually and is relatively uniform throughout the year. The lowest and highest rainfall months are October with about 4.5 inches and March with nearly 8 inches. Rainfall extremes of

over 10 inches can occur during any month, but rainfall is less than 2 inches per month only 5 percent of the time. Precipitation varies widely over short distances because topographic features modify wind patterns and rainfall distribution. Also, an orographic effect causes an approximate 13-inch difference in rainfall between low and high elevation watersheds.

The maximum and minimum air temperatures on record are 98 and —15°F. Annual maximums may occur anytime between June and the end of September, and minimums can occur between November and March. The average maximum and minimums are 92° and 1°F, respectively; and the mean annual temperature is 54.7°F. Pan evaporation averages 35 inches and has varied from 31 to 39 inches ± a standard error of 0.35 inch. Less than 1 inch of pan evaporation is common in December and January; and between May and October, pan evaporation ranges from about 3 to 5 inches per month.

#### *Geology, Physiography, Soils*

The laboratory is in the Nantahala range of the Blue Ridge Mountains. Underlying rock is classified as Carolina gneiss from the Precambrian era. Granite gneiss, mica gneiss, and mica schists are all represented and have undergone complex folding.

Topography is steep, and elevations range from 2,220 to 5,223 feet. Average slope of the basin (max.-min. elevation/distance) is 19 percent, but individual watersheds are considerably steeper. Slopes in places exceed 100 percent, and some rock outcrops are found on steep slopes at high elevations.

Soils vary because of differences in parent material, topography, and elevation. At lower elevations, soil horizon development is complete, but immature soils are found on higher, cooler sites. Soils are highly permeable; infiltration rates frequently exceed 50 inches per hour, and runoff over the soil surface is virtually unknown on undisturbed sites. The regolith is deep; drilling has shown that porous material is sometimes over 70 feet deep and averages perhaps 20 feet deep.

#### *Vegetation*

Basin vegetation was originally dominated by American chestnut, oak, and hickory. In 1909, several small logging operations began and continued intermittently until 1918, when the land was acquired and timber rights reserved by the Forest Service. Logging continued until 1923, but no trees smaller than 15 inches diameter on the stump were cut. Cruises made in 1933 showed that basal area at mid and upper elevations often exceeded 150 square feet/acre. Between 1930 and 1945, chestnut was blight-killed, and basal area was reduced on all watersheds.

Currently, about 60 species of hardwoods are indigenous in the basin; and hemlock, pitch pine, and eastern red cedar are the native conifers. The type groups, as described by the Society of American Foresters, are oak-hickory, pitch pine-oak, northern red oak, and yellow-poplar. The abundant understory is composed of hardwood saplings, mountain laurel, rhododendron, blueberry and huckleberry, azalea, and less numerous trees and shrubs. Ground cover consists of grasses, anemones, asters, bedstraw, ferns, trilliums, violets, mayapples, and mosses.

### TREATMENT EFFECTS ON WATER YIELD

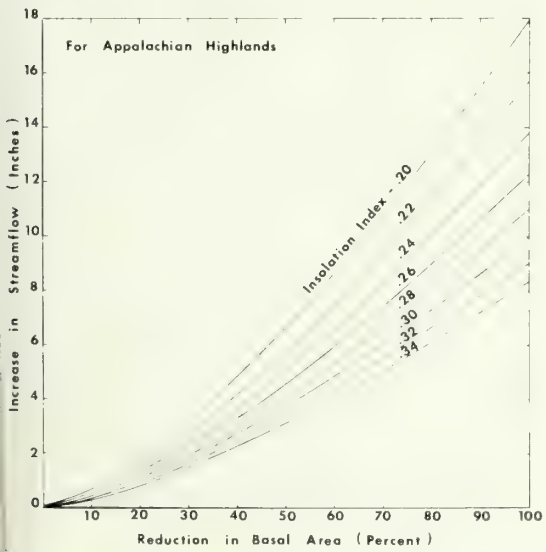
Water yields have been measured at Coweeta after cutting or deadening part or all of the vegetation and after conversion from hardwood to another cover type.

In his survey paper, Hibbert *(1966)*

concluded that the increase in streamflow after removal of hardwood cover at Coweeta was proportional to the amount of cover removed. He also noted that the streamflow increase was much greater for north- than for south-facing watersheds. Prediction of the increase in flow after cutting or deadening the forest can be improved simply by grouping watersheds by aspect.

To explain the difference in streamflow observed when north- and south-facing watersheds are cut, Swift *(1960)* studied the theoretical solar energy available for evapotranspiration. He found little difference in incoming extraterrestrial radiation during the growing season but considerably more radiation on south- than north-facing watersheds during the dormant season. Total and net radiation patterns were found to be similar in form to theoretical patterns *(Swift 1972)*, and we hypothesized that streamflow response to cutting was inversely proportional to solar energy input.

Figure 1.—First-year increase in streamflow determined from the percent reduction in forest stand basal area and the insolation index of the watershed.




Using data on basal area cut and potential insolation from Coweeta, Hubbard Brook, Fernow, and Pennsylvania State University watersheds, a prediction equation was derived for the first-year streamflow increase after cutting hardwood forests. Potential insolation on a map area basis was calculated by the methods of Lee *(1963)* and Swift *(1973)*.

The model for predicting the first-year change in yield is:

$$\triangle Q = a \left( \frac{X_1}{X_2} \right)^b$$

where $\triangle Q$ is the first-year increase in streamflow in inches, $X_1$ is the percent basal area cut, $X_2$ is potential annual insolation in langleys (insolation index), and a and b are coefficients. For convenience, the insolation index for each watershed was coded by multiplying by $10^{-6}$. Regression analysis yielded the equation

$$\triangle Q = .00224 \left( \frac{X_1}{X_2} \right)^{1.1462}$$

This equation whose $r^2$ is 0.89, is graphically represented in figure 1.

To predict the increase in streamflow for any year after silvicultural practices are applied, the first-year increase, the duration of the increase, and a model for describing the time-duration relationship of the increases in streamflow are required. Douglass and Swank *(1972)* presented the time-duration model for a regrowing forest as:

$$\triangle Qi = a + b(\log Ti)$$

where $\triangle Qi$ is the increase in flow in year i, a is the first-year increase, Ti is the ith year after treatment, and b is a coefficient. The total duration of an increase in streamflow with regrowth allowed is estimated from the relationship between the first-year streamflow

increase and duration of increased flow observed on experimental watersheds. The duration of the increase is approximately equal to 1.57 times the first-year yield increase.

To illustrate the use of these equations, consider a hardwood forest, a 50-percent basal area cut, and a potential insolation of 260,000 calories/square centimeter. Using Equation 1, the first-year yield increase is

$$\triangle Q = .00224 \left( \frac{50}{.26} \right)^{1.1462}$$

$$\triangle Q = 4.49 \text{ inches}$$

The duration of the increase is estimated to be

$$T = 1.57 \text{ (first-year increase)}$$
$$T = 1.57 \ (4.49)$$
$$T = 7.04 \text{ rounded to 7 years}$$

The estimating equation for a yield increase in any year i is obtained by solving Equation 2 for b when $T = 7$ and $\triangle Q_7 = 0$. Thus,

$$\triangle Q_7 = a + b(\log Ti)$$
$$0 = 4.49 + b(\log 7)$$
$$b = -5.31$$

and the final equation becomes

$$\triangle Qi = 4.49 - 5.31(\log Ti).$$

The expected yearly increases in streamflow are

| *Year after cutting* | *Increase, in inches* |
|---|---|
| 1 | 4.49 |
| 2 | 2.89 |
| 3 | 1.96 |
| 4 | 1.29 |
| 5 | .78 |
| 6 | .36 |
| Total | 11.77 |

Now consider the second type of experiment. Conversions of vegetative types at Coweeta have produced dramatic changes in streamflow, which should be of interest to managers of municipal watersheds.

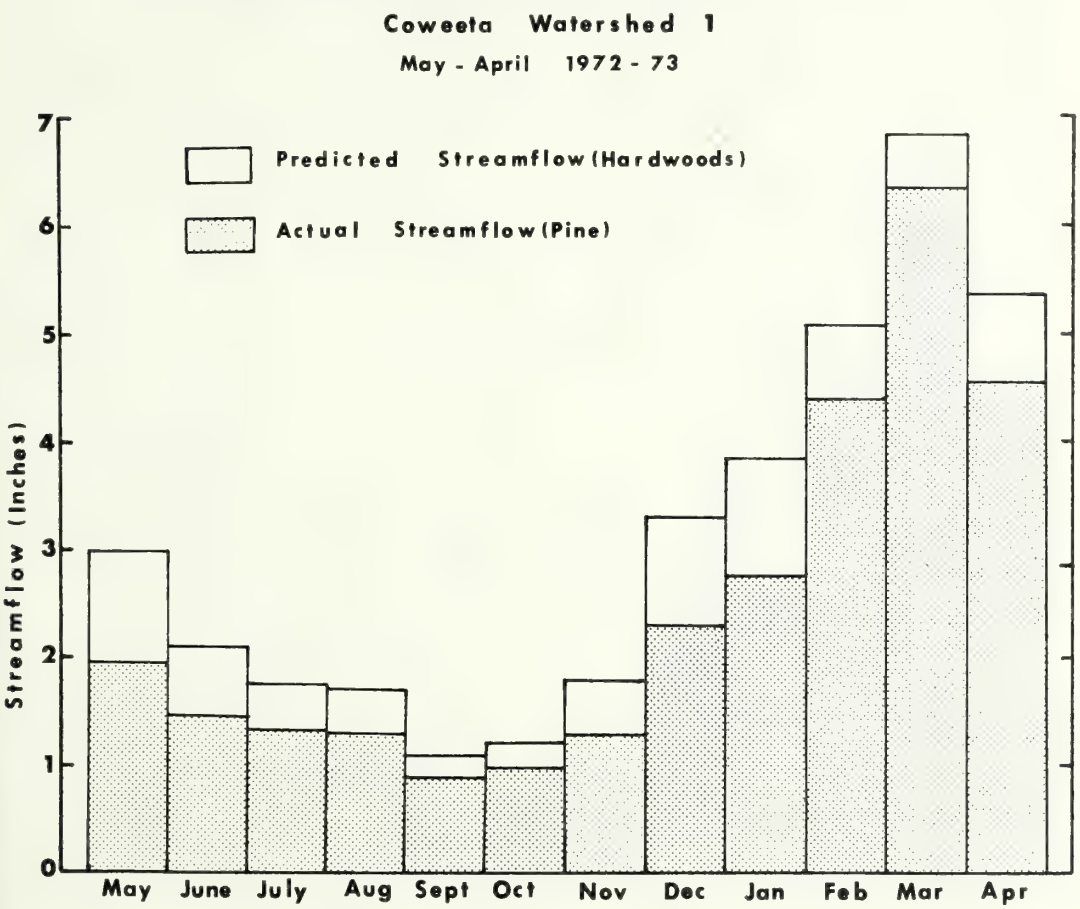
In two experiments, conversion of hardwoods to white pine on a north- and south-facing watershed greatly reduced streamflow. For the first 6 years, the streamflow increases were about as expected for clearcut hardwood forests. Then, streamflow on both watersheds declined at a rate of 1 to 2 inches per year for the next 3 years. By age 10 years, the white pine was using more water than the original hardwood cover *(Swank and Miner 1968)*.

Over the last 4 years, the rate of streamflow reductions has tended to level off; but in 1973, when the pines were about 16 years old, flow was approximately 8 inches (25 percent) less than the flow expected if the watersheds had remained in a hardwood cover.

On a south-facing watershed, monthly streamflow reductions of 0.5 to 1.1 inch were observed during the dormant and early growing season (November through June) of 1972-73 (fig. 2). Streamflow was reduced about 0.4 inch in July and August, and reductions in flow tapered off to about 0.2 inch in September and October. Although reductions appear to be small in August through October, streamflow is normally lowest during these months. These reductions represent a 16- to 30-percent decrease in monthly flow from the previous hardwood cover. Similar reductions in streamflow were observed for the north-facing white pine-covered watershed.

The greater evaporative losses from pine than from hardwoods are due to greater interception and transpiration losses. Experimental data derived from Helvey's studies *(1967)* showed that interception and subsequent evaporation of rainfall is greater for pine than hardwoods during the dormant season. Interception loss is a function of the plant

Figure 2.—Changes in streamflow after a south-facing hardwood-covered watershed was converted to white pine in 1957.



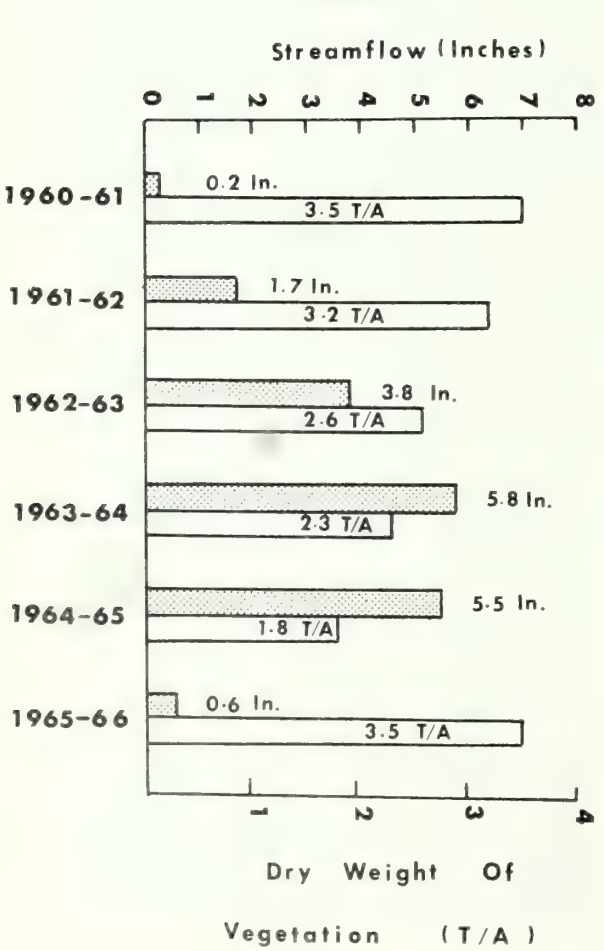

surface area, and the surface area in a hardwood stand is drastically reduced by leaf fall. Thus, in the dormant season, the ratio of leaf surface area to ground area (leaf area index or LAI) for hardwoods is less than 1, whereas Swank and Schreuder *(1973)* estimated that the LAI was 9.9 for the white pine on Watershed 1 in the winter of 1972. Consequently, less precipitation reaching the soil under pine caused lower streamflow during the dormant season. A further reduction in streamflow is attributed to greater transpiration within the pine canopy, at least during certain months.

In spring and summer, atmospheric conditions favor high evaporation. In April and May, when pine is in full leaf and hardwoods are leafing out, combined interception and transpiration losses are much greater from pine. Even after hardwoods are in full leaf, maximum LAI is only about 6 *(Whittaker and Woodwell 1967)* compared to a peak LAI of 17.8 for the pine on Watershed 1 *(Swank and Schreuder 1973)*. Although Raber *(1937)* concluded that the summer transpiration rate of hardwoods per unit of leaf area is greater than for conifers, transpiration per stand may be greater for pine because of the larger transpiring surface. Greater transpiration and greater interception losses cause streamflow from white pine forests to be lower than from hardwood

forest throughout the year. The conclusion is inescapable: If maximum water yield is desired, conifers are a poor choice for a watershed cover.

Conversion from hardwood to grass also significantly alters streamflow. Hibbert *(1969)* removed merchantable timber from a 22-acre hardwood forest, prepared a seedbed by burning, grubbing, and harrowing, applied 3 tons of lime and 1 ton of 2-12-20 fertilizer per acre, and seeded Kentucky 31 fescue at a rate of 20 pounds per acre. An increase in water yield was expected, but it did not appear in the first year after treatment. Grass productivity was very high — 3.5 tons of dry matter per acre — but it declined to 1.8 tons per acre by the end of the 5th growing season. As grass productivity declined, streamflow increased. During the 4th and 5th year under grass, the watershed yielded over 5 inches of extra water each year (fig. 3). To verify the inverse relation between change in streamflow and grass productivity, the grass was refertilized in 1965; productivity increased to 3.5 tons per acre, and streamflow again dropped back to that expected from a hardwood cover. Grass also appeared to evaporate more water in the spring and less water in the late summer than the original forest cover. Thus, a grass cover of low vigor can significantly increase streamflow.

Figure 3.—Annual yield change and gross dry-matter weight per acre after a hardwood-covered watershed was converted to grass.

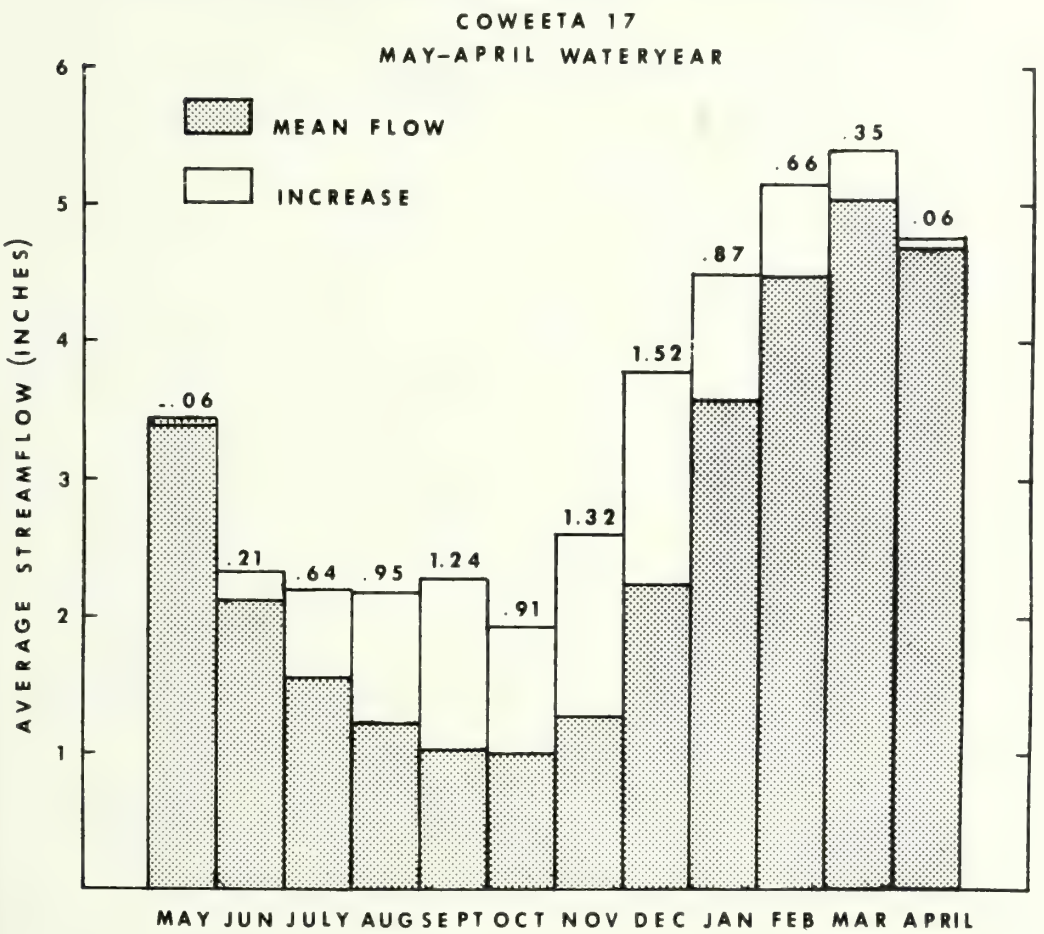



## TREATMENT EFFECTS ON DISTRIBUTION OF FLOW

Douglass and Swank *(1972)* presented data on average monthly flow rates before trees were cut and during 7 years when sprouts were cut annually from Watershed 17 (fig. 4). These data are representative of other experiments at Coweeta. A forest cover had no measurable effect on monthly flow when soil storage space was charged with moisture (season of high flows). Before and after clearcutting, the watershed contained nearly equal volumes of water during late winter and early spring, and the hydrologic response was about the same.

As the growing season progressed, however, the difference in moisture storage between the cut and forested conditions progressively increased. Drainage reaching the stream shortly after a rain was proportional to the moisture storage difference between the forest and clearcut conditions. Streamflow increases began in about June and increased in magnitude as the growing season advanced. In September, October, and November,

Figure 4.—Average monthly streamflow and the increase in flow during 7 years of annual recutting on Watershed 17.



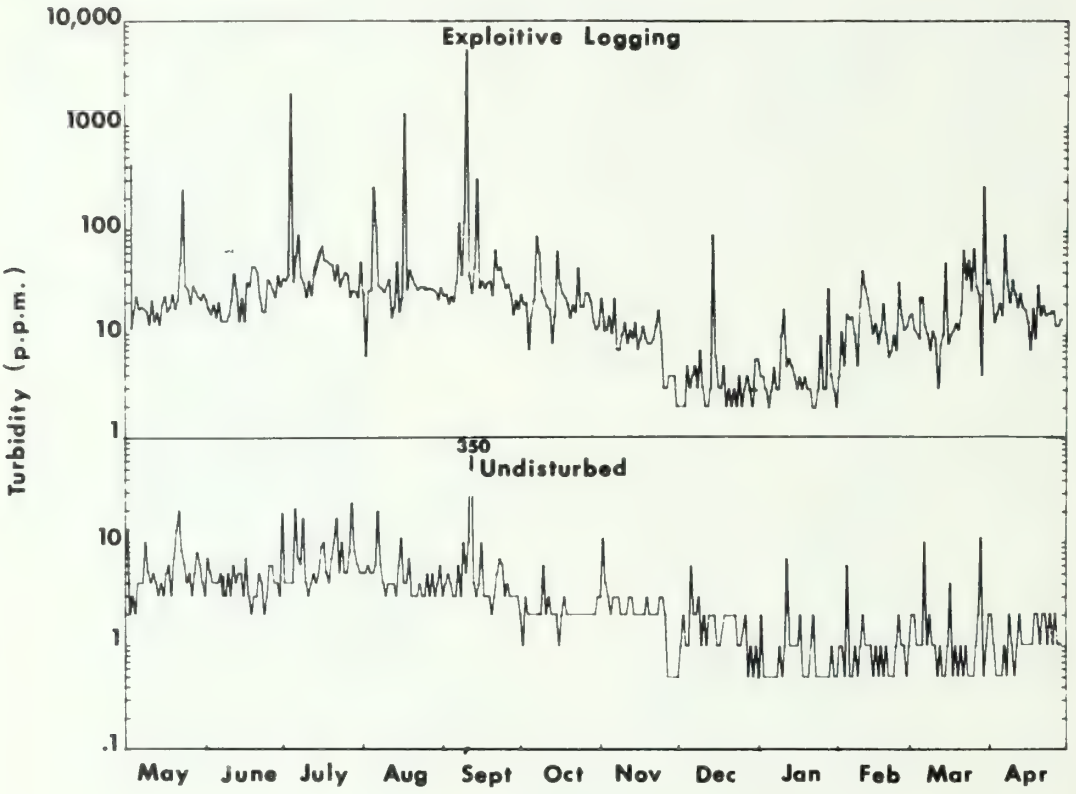

streamflow was increased by 100 percent. This is precisely the season when demand for water is greatest and unregulated flow is lowest. Large increases continued until December and then declined as the difference in moisture storage between clearcut and forested conditions declined. For treatments which produce less drastic storage differences, recharge occurs more quickly and increases are not delayed as late into the winter.

Timing of flow can be improved or degraded by treating the vegetation. Those practices which increase total annual flow produce large quantities of extra water during the low-flow periods. Conversely, streamflow during low-flow months is reduced by practices which decrease annual streamflow. Conversion to pine reduces flows during all months primarily because of interception and transpiration differences between pine and hardwoods at that stand age.

## TREATMENT EFFECTS ON WATER QUALITY

The criteria of water quality vary with the intended use of the water. At Coweeta, turbidity, temperature, and mineral content of water have been measured.

Figure 5.—Comparison of turbidity from an exploitive logging and an undisturbed hardwood-covered watershed from May 1947 through April 1948.




Between 1942 and 1954, a 212-acre watershed was clearcut, and the logger selected road sites and logging technique. Roads were poorly constructed, often traversing steep grades without proper drainage, water bars, or grass cover. Between storms, turbidity on the logged watershed was much greater than from an undisturbed control watershed; and during storms, turbidity on the logged watershed was 10 to 20 times greater (fig. 5). Maximum turbidity recorded for the year was 5,700 ppm, but measurements were usually taken at about the same time each day and it is probable that maximum turbidity was often much greater. On a watershed that was logged properly from well-designed roads, turbidity increased only slightly. Cutting where soils were not disturbed by roads or skidding and converting from hardwood to pine did not discernibly increase turbidity. In general, we at Coweeta have concluded, as did Packer *(1966)*, that poorly designed and poorly located roads are the main cause of deterioration in water quality.

A 23-acre forested watershed at Coweeta was cut in 1940; and 6 acres were planted to corn, 7 acres were put into pasture, and 10 acres were allowed to grow back to hardwood coppice. Before treatment, soil losses averaged 156 pounds per acre. Dils *(1953, 1957)* found that soil losses varied from about 400 to over 18,000 pounds per acre during the 13 years of farming. Since eroded soil came from the corn field, pasture,

and stream channel, losses cannot be assigned to any single source. After the pasture and corn field were planted to grass and later to white pine and yellow-poplar, soil losses for the next 15 years averaged only 128 pounds per acre annually compared to 2,047 pounds per acre for the farming period.

Manipulation of the forest can also change water chemistry.[1] Mineral cycling in four contrasting ecosystems has been studied intensively at Coweeta since 1968. Annual budgets and seasonal fluctuations of $Ca^{++}$, $Mg^{++}$, $K^{+}$, and $Na^{+}$ for watersheds with a hardwood, a grass-to-forest succession, a hardwood coppice, and an eastern white pine cover were reported by Johnson and Swank *(1973)*. Cation budgets varied by watershed, but drastic alterations of the forest ecosystem have not caused a long-term loss of cations by erosion or drainage waters.

Relatively minor changes in mean annual concentrations of cations and anions on Coweeta watersheds treated in a variety of ways support these findings (table 1). Of the cations studied, only calcium concentrations from two watersheds to which lime had been applied were appreciably higher than would be expected from undisturbed watersheds. Of the anions studied, only $NO_3$-N increased in concentrations after treatment. Mean annual concentration of $NO_3$-N on treated watersheds was from about 4 to 150 times that on undisturbed watersheds, but the maximum concentration observed (grass-to-forest succession) was only 1.23 ppm. The next-to-highest concentration of 0.25 ppm was observed after hardwood-to-white pine conversion, compared with 0.002 to 0.013 ppm for undisturbed watersheds.

The concentrations of all cations and anions on treated watersheds are quite low, and the increased export of nutrients is insufficient to create pollution problems for drinking water or to degrade fertility. Similar observations on other, more recent clearcuttings in western North Carolina appear to support the findings at Coweeta, but data collection is not complete.

Herbicides and pesticides used in forestry operations can pollute water. On a grass-covered watershed, the grass cover was killed with atrazine and paraquat in May 1966 and re-treated with atrazine and 2,4-D in July of the same year *(Douglass et al. 1969)*. During the first spraying, grass hanging directly over the stream was treated, and low concentrations of atrazine and paraquat were detected in streamflow. Concentrations of atrazine were highest (20 to 40 ppb) during rains immediately after spraying, when intercepted water carried herbicides directly into the stream. After 30 days, concentrations of atrazine were always less than 10 ppb, and paraquat could no longer be detected.

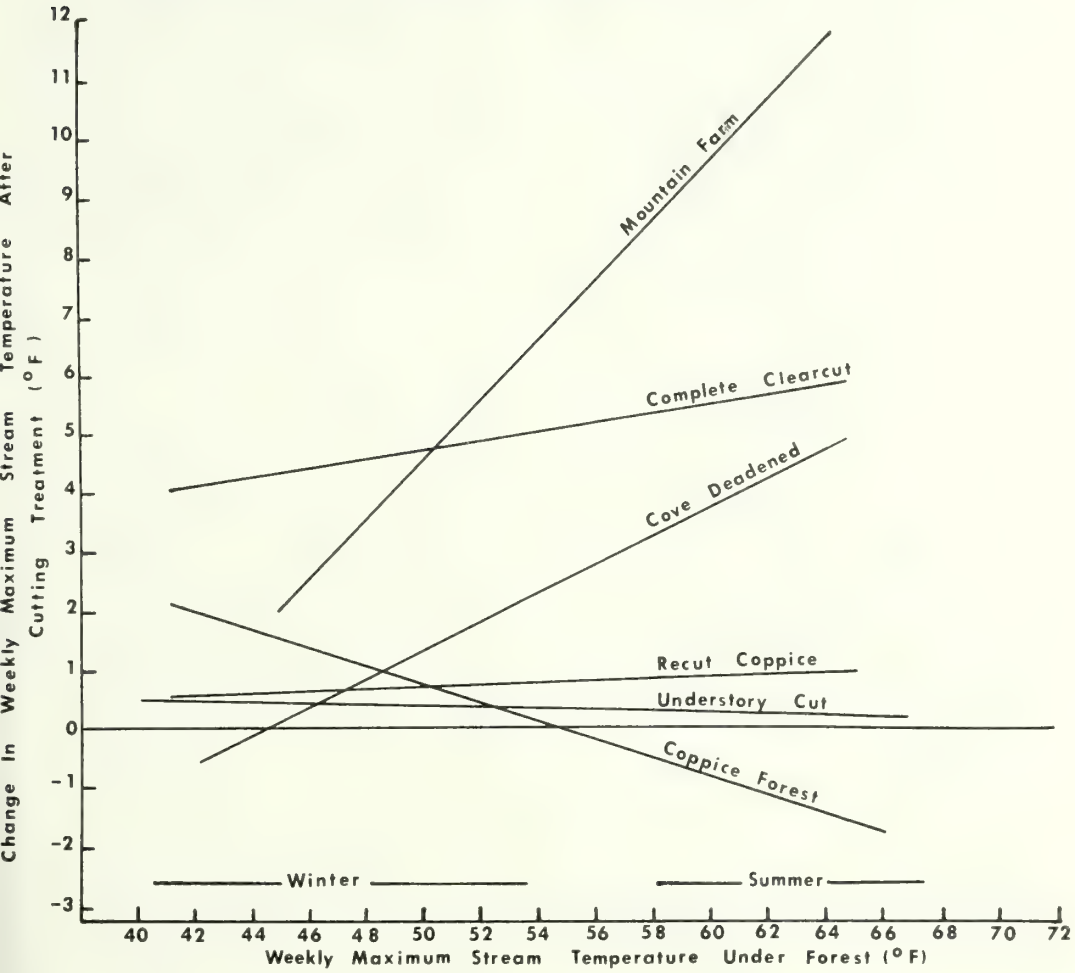
During the second spraying, a 10-foot strip on either side of the channel was left unsprayed. No increase in atrazine and no trace of 2,4-D was detected after the second treatment. Similarly, Grzenda et al. *(1964)* observed that when entire watersheds were broadcast-sprayed from fixed-wing aircraft to control elm spanworm, low levels of DDT were detected in streams. But when spraying was restricted mainly to ridges and slopes away from streams, DDT was not detected in the streams. Since most water reaches the streams at Coweeta through the soil rather than as overland flow, water quality is adequately pro-

[1]Water chemistry analyses supported in part by the Southeastern Forest Experiment Station, Forest Service, United States Department of Agriculture, and in part by the University of Georgia, Eastern Deciduous Forest Biome, US-IBP, funded by the National Science Foundation under Interagency Agreement AG 199, 40-193-69 with the Atomic Energy Commission —Oak Ridge National Laboratory.

Table 1.—pH and concentration of selected ions, in ppm, May 1972 through April 1973.

| WS No. | Treatment | pH | | $NO_3$-N | | $NH_4$-N | | $PO_4$-P | | Cl | | K | | Na | | Ca | | Mg | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Min. Max. | Mean | Min. Max. | Mean | Min. Max. | Mean | Min. Max. | Mean | Min. Max. | Mean | Min. Max. | Mean | Min. Max. | Mean | Min. Max. | Mean | Min. Max. |
| | | | 4.90 | | .001 | | .001 | | .001 | | .560 | | .187 | | .929 | | .620 | | .200 |
| 1 | 15-yr-old white pine | 6.71 | 7.40 | .029 | .077 | .003 | .020 | .006 | .022 | .660 | .920 | .580 | 1.189 | 1.111 | 1.748 | .731 | 1.125 | .368 | .523 |
| 3 | 7.4 acres in 16-yr-old poplar<br>5.4 acres in 16-yr-old white pine<br>10 acres in 32-yr-old coppice (old mountain farm) | | 5.40 | | .001 | | .001 | | .001 | | .480 | | .177 | | .741 | | 4.820 | | .379 |
| | | 6.87 | 7.50 | .015 | .038 | .004 | .033 | .006 | .022 | .568 | .970 | .441 | .935 | 1.046 | 1.575 | 6.057 | 7.317 | .485 | .680 |
| | | | 5.00 | | .230 | | .001 | | .001 | | 1.060 | | .203 | | .896 | | .971 | | .292 |
| 6 | Grass-to-forest succession | 6.73 | 7.30 | .619 | 1.230 | .004 | .010 | .007 | .030 | 1.381 | 2.490 | .588 | 1.909 | 1.140 | 1.374 | 1.118 | 1.493 | .640 | .820 |
| | | | 6.00 | | .003 | | .001 | | .001 | | .408 | | .177 | | .534 | | .368 | | .189 |
| 13 | 10-yr-old coppice | 6.63 | 7.40 | .044 | .084 | .003 | .014 | .004 | .013 | .491 | .672 | .426 | .922 | .698 | 1.220 | .501 | .849 | .285 | .617 |
| | | | 5.65 | | .030 | | .001 | | .001 | | .400 | | .183 | | .663 | | .388 | | .145 |
| 17 | 16-yr-old white pine | 6.72 | 7.40 | .154 | .249 | .004 | .012 | .012 | .336 | .485 | .675 | .446 | .946 | .835 | 1.338 | .577 | .827 | .247 | .374 |
| 28 | 180 acres clearcut, 80 acres thinned, 96 acres undisturbed | | 6.05 | | .010 | | .001 | | .001 | | .390 | | .200 | | .655 | | .684 | | .275 |
| | | 6.66 | 7.40 | .094 | .208 | .003 | .017 | .004 | .020 | .493 | .890 | .465 | 1.051 | .901 | 1.692 | 1.021 | 1.319 | .454 | .675 |
| | | | 5.75 | | .072 | | .001 | | .001 | | .300 | | .174 | | .500 | | .256 | | .203 |
| 37 | 10-yr-old coppice | 6.58 | 7.35 | .149 | .246 | .004 | .038 | .006 | .095 | .442 | .783 | .424 | .975 | .667 | 1.231 | .742 | 1.128 | .312 | .637 |
| | | | 5.90 | | .001 | | .001 | | .001 | | .490 | | .257 | | 1.060 | | .488 | | .233 |
| 2 | Undisturbed hardwoods | 6.91 | 7.85 | .004 | .017 | .002 | .020 | .006 | .020 | .673 | .922 | .589 | 1.368 | 1.351 | 1.676 | .713 | 1.036 | .359 | .552 |
| | | | 5.50 | | .001 | | .001 | | .001 | | .450 | | .161 | | .603 | | .196 | | .196 |
| 14 | Undisturbed hardwoods | 6.76 | 7.30 | .004 | .024 | .004 | .031 | .005 | .017 | .544 | .738 | .369 | .817 | .772 | 1.087 | .513 | 1.186 | .292 | .416 |
| | | | 5.60 | | .001 | | .001 | | .001 | | .460 | | .206 | | .674 | | .448 | | .156 |
| 18 | Undisturbed hardwoods | 6.77 | 7.35 | .003 | .014 | .004 | .022 | .005 | .018 | .554 | .880 | .479 | 1.022 | .930 | 1.424 | .685 | .891 | .317 | .457 |
| | | | 5.08 | | .001 | | .001 | | .001 | | .428 | | .163 | | .551 | | .326 | | .157 |
| 21 | Undisturbed hardwoods | 6.55 | 7.35 | .003 | .016 | .004 | .024 | .004 | .029 | .490 | .800 | .381 | .735 | .717 | 1.097 | .530 | .864 | .228 | .364 |
| | | | 5.65 | | .001 | | .001 | | .001 | | .425 | | .106 | | .400 | | .255 | | .163 |
| 27 | Undisturbed hardwoods | 6.60 | 7.60 | .013 | .050 | .005 | .024 | .004 | .018 | .499 | .675 | .243 | .511 | .529 | .841 | .384 | .662 | .209 | .307 |
| | | | 5.05 | | .001 | | .001 | | .001 | | .430 | | .137 | | .541 | | .304 | | .220 |
| 32 | Undisturbed hardwoods | 6.45 | 7.45 | .003 | .015 | .003 | .013 | .004 | .013 | .491 | .722 | .322 | .843 | .665 | .940 | .550 | .815 | .295 | .381 |
| | | | 5.35 | | .001 | | .001 | | .001 | | .425 | | .198 | | .692 | | .591 | | .262 |
| 34 | Undisturbed hardwoods | 6.76 | 7.50 | .002 | .019 | .003 | .024 | .006 | .019 | .556 | .775 | .429 | 1.065 | .931 | 1.322 | .749 | .922 | .353 | .453 |
| | | | 5.00 | | .001 | | .001 | | .001 | | .438 | | .146 | | .500 | | .421 | | .203 |
| 35 | Undisturbed hardwoods | 6.77 | 7.30 | .008 | .030 | .003 | .030 | .004 | .014 | .545 | .778 | .342 | .740 | .824 | 1.352 | .670 | 1.244 | .277 | .348 |

Figure 6.—Effect of six cutting treatments on weekly maximum stream temperature at the Coweeta Hydrologic Laboratory.




tected by the simple precaution of not spraying streamside vegetation where throughfall or stemflow can flush chemicals directly into streams or ditchlines.

Increased stream temperature can adversely affect or even kill trout. Swift and Messer *(1971)* summarized the effects of 6 watershed treatments at Coweeta on stream temperature (fig. 6). Where forest types and all understory vegetation were completely cut, maximum stream temperatures increased from the normal 66°F to 73°F or more. Mountain farming raised summer maximum temperatures over 12°F above normal. In other treatments where streambank vegetation was not cut or had regrown, summer maximum temperatures were unchanged or even lowered slightly. Swift and Baker *(1973)* found that if a buffer strip is retained to shade the water surface, temperatures of streams are not adversely affected by treatment of the rest of the watershed.

## SUMMARY

The watershed experiments at Coweeta provide numerous detailed conclusions that are useful to watershed managers. Some of the most significant are:

1. Cutting the mixed hardwood cover in the southern Appalachians increases annual streamflow in proportion to the amount of cover removed.
2. The streamflow increase after cutting is approximately twice as great from north-facing watersheds as from south-facing watersheds. Equations for predicting changes in water yield after cutting are based on the proportion of the stand basal area cut and the potential insolation of the watershed.
3. Converting Coweeta watersheds from hardwoods to white pine greatly reduces streamflow.
4. Converting a hardwood to a low grass cover can significantly increase streamflow.
5. Timing of streamflow can be improved or degraded by treating vegetation. When annual flow is increased, extra water is produced during low-flow periods; those practices that decrease annual flow reduce streamflow during the low-flow months.
6. Poorly designed and poorly located logging roads are the main source of high turbidities connected with logging operations. Road specifications that minimize turbidity are available for mountainous terrain.
7. Water pollution from sprayed herbicides and pesticides can usually be prevented by not spraying streamside vegetation.
8. Stream temperatures are not increased by forest cuttings if a buffer strip is retained to shade the stream.
9. Water chemistry studies to date provide no evidence that forest cuttings in the mountains of North Carolina have rendered streamflow less fit for human use or degraded soil fertility.

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# EFFECTS OF MANAGEMENT PRACTICES ON WATER QUALITY AND QUANTITY: FERNOW EXPERIMENTAL FOREST, W. VIRGINIA

*by* JAMES N. KOCHENDERFER *and* GERALD M. AUBERTIN, *Research Forester and Research Soil Scientist, USDA Forest Service, Northeastern Forest Experiment Station, Timber and Watershed Laboratory, Parsons, West Virginia.*

*ABSTRACT.* Results of 22 years of forest hydrology research on the Fernow Experimental Forest are reviewed. Forest influences were measured on quantity and timing of streamflow and on parameters of water quality such as turbidity, temperature, specific conductance, pH, alkalinity, and nutrient concentrations. These results indicate that it is currently not practical to manage forest land for both sustained increased water yield and merchantable timber products, and that forest land can be managed for a variety of uses without impairing water quality if these uses are regulated intelligently.

THE FERNOW Experimental Forest, near Parsons, West Virginia, was established in 1934 for forest research and the demonstration of its results. Containing 3,640 acres and representing the major hardwood types found in the central Appalachians, the Forest is located in the unglaciated Allegheny Plateau region of north-central West Virginia. This section of the Allegheny mountains is characterized by steep mountains and narrow valleys. The average elevation of the study area is about 2,500 feet above sea level. The predominant soil is Calvin silt loam *(Losche and Beverage 1967)* underlain with fractured sandstone and shale of the Hampshire (formerly Catskill) formation. Soil depth is normally less than 5 feet.

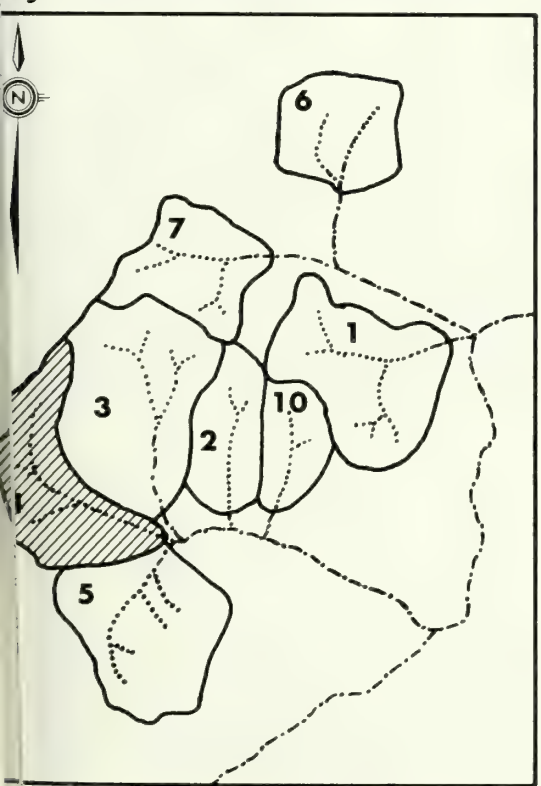
Timber stands on the watersheds before treatment were 40 to 50 years old, with many scattered older residuals. Vegetation on the watersheds fits into Core's *(1966) mixed hardwood forests* floristic province. Common tree species on the better sites are yellow-poplar *(Liriodendron tulipifera* L.), sugar maple *(Acer saccharum* Marsh.), black cherry *(Prunus serotina* Ehrh.), white ash *(Fraxinus americana* L.), basswood *(Tilia americana* L.), and red oak *(Quercus rubra* L.). The dominant tree species on the poorer sites are various species of oak *(Quercus* spp.), hickory *(Carya* spp.), sourwood *(Oxydendrum arboreum* (L.) DC.), and sassafras *(Sassafras albidum* (Nutt.) Nees.). Sawtimber volumes varied from 7,000 to 13,000 board feet per acre.

The growing season extends from 1 May through 31 October, the dormant season from 1 November through 30 April. Annual precipitation is evenly distributed between the dormant and growing seasons, averaging 56 inches on the control watershed for a 21-year period. Annual runoff from the control watershed for the same period of record averaged 24 inches, 6 inches during the growing season and 18 inches during the dormant season. Potential evapotranspiration on the Fernow Forest was estimated to be 22 inches per year *(Patric and Goswami 1968)*.

## THE STUDIES

We have eight gaged watersheds on the Fernow Forest (fig. 1), ranging in size from 38 to 96 acres. Collection of streamflow and climatic data began on watersheds 1 to 5 in 1951, on watersheds 6 and 7 in 1957. Stream discharge, turbidity, pH, alkalinity, specific conductance, and temperature data were collected from each watershed for a period of 6 years. Data obtained during this calibration period were used as a base for evaluating changes due to treatment.

Figure 1.—Location of the watersheds on the Fernow Experimental Forest, Parsons, West Virginia.




After calibration, one of the original five watersheds (No. 4) was retained as an untreated control, and the others underwent different cutting treatments. These treatments and their hydrologic effects have been described by Reinhart et al. *(1963)*. Watersheds 6 and 7 were treated in 1963; results of this experiment have been presented by Patric and Reinhart *(1971)*. Water-quality studies were expanded in 1969 to include measurements of calcium, magnesium, potassium, sodium, phosphate, nitrate-N, ammonium-N, sulfate, iron, manganese, zinc, and copper. A summary of the watershed treatments is presented in table 1.

Stream discharge is measured with 120° V-notch weirs. Precipitation is measured in a network of 4 recording gages and 14 standard 8-inch rain gages. Water temperatures are measured with both recorders and maximum-minimum thermometers. Water samples are obtained weekly by grab sampling, with some additional sampling during storm periods.

## WATER QUALITY

Of the many water-quality parameters studied, the best known and most easily obtained are turbidity, temperature, specific conductance, pH, and alkalinity.

### *Turbidity*

Bare soil exposed by road-building, and to a much less extent by log landings, has long been recognized as the major source of stream sediment associated with logging operations. Turbid-

Table 1.—Summary of treatments on Fernow watersheds

| Watershed number and size (acres) | Type of treatment | Treatment date | Basal area[1] cut | Original sawtimber volume[2] | Sawtimber cut |
|---|---|---|---|---|---|
| | | | *Percent*[4] | *Bd. ft./acre* | *Percent*[4] |
| 1 (74) | Clearcut to about 6 inches dbh except for culls.[3] | 5/57–6/58 | 74 | 9,926 | 86 |
| | Applied 500 lbs/acre of 45% urea. | 5/71 | — | — | — |
| 2 (38) | 17-inch diameter limit cut, entire watershed. | 6/58–8/58 | 32 | 7,145 | 59 |
| | 17-inch diameter limit cut, 27 acres of watershed; in both cuts, culls larger than 17 inches were cut. | 9/72–10/72 | 12 | — | — |
| 3 (85) | Intensive selection cut including cull treatment in trees above 5 inches dbh. | 10/58–2/59 | 13 | 8,300 | 20 |
| | Same treatment. | 9/63–10/63 | 8 | 7,848 | 12 |
| | 0.4-acre patch cuttings totaling 5.6 acres; everything cut down to 5 inches; 1- to 5-inch stems basal sprayed with herbicide. | 7/68–8/68 | 6 | 8,435 | 6 |
| | Clearcut to 1-inch dbh. | 7/69–5/70 | 91 | 7,928 | 91 |
| 5 (90) | Extensive selection cut, including cull treatment in trees larger than 11 inches dbh. | 8/58–11/58 | 20 | 11,993 | 31 |
| | Same treatment. | 2/68–6/68 | 14 | 13,020 | 19 |
| 6 (54) | Lower half (27 acres) of watershed clearcut. | 3/64–10/64 | 51 | 10,948 | 51 |
| | Maintained barren with herbicides. | 5/65–10/69 | | | |
| | Upper half (27 acres) of watershed clearcut. | 10/67–2/68 | 49 | 11,224 | 49 |
| | Maintained barren with herbicides. | 5/68–10/69 | | | |
| | Entire watershed maintained barren with herbicides. | 2/68–10/69 | 100 | — | 100 |
| 7 (59) | Upper half (29.5 acres) of watershed clearcut. | 11/63–3/64 | 49 | 13,758 | 51 |
| | Maintained barren with herbicides. | 5/64–10/69 | | | |
| | Lower half (29.5 acres) of watershed clearcut. | 10/66–3/67 | 51 | 13,193 | 49 |
| | Maintained barren with herbicides. | 5/67–10/69 | | | |
| | Entire watershed maintained barren with herbicides. | 2/68–10/69 | 100 | — | 100 |

[1]Basal area as used in this report refers to the total basal area in trees 1 inch in diameter and larger.
[2]Trees 11 inches dbh and larger.
[3]No care was exercised on the road system.
[4]Based on the total basal area and sawtimber volume on the entire watershed.

ity, an optical index of sediment suspended in water, is often interpreted as an index to water quality that is closely related to logging activity. Careless logging caused very turbid water; but logging on carefully located, constructed, and maintained road systems caused only minor increases in turbidity (table 2).

Watershed 1 (commercially clearcut) produced a maximum of 56,000 turbidity units, measured while logging was in process. Turbidity levels were high during and immediately after logging,

Table 2.—Turbidity values for selected Fernow watersheds

| Period | Average turbidity non-stormflow | Range in turbidities, including stormflow |
|---|---|---|
| | *In Jackson turbidity units* | |
| Commercial clearcut (watershed 1): | | |
| During logging operation | 490 | 0–56,000 |
| First year after logging | 38 | 0–5,000 |
| Second year after logging | 2 | 0–170 |
| Silvicultural clearcut (watershed 3): | | |
| During logging operation | 6 | 0–90 |
| First year after logging | 5 | 0–35 |
| Second year after logging | 2 | 0–23 |
| Undisturbed control (watershed 4): | | |
| 5/59–11/72 | 2 | 0–25 |

but decreased rapidly after disturbance ended. By contrast, watershed 3 was logged with a carefully planned and maintained road system, and it produced only minor increases in turbidity.

### *Temperature*

Stream temperatures were raised by some of the cutting practices used on the Fernow Forest. Average maximum stream temperature on watershed 1 increased about 8°F during the first growing season after cutting. Temperatures returned to pre-cutting levels within 5 years after cutting. Deforesting and herbiciding the lower halves of watersheds 6 and 7 also substantially increased growing-season stream temperatures, but deforesting and herbiciding the upper halves had no appreciable affect. There was, of course, no channel exposed to direct insolation on the deforested upper halves.

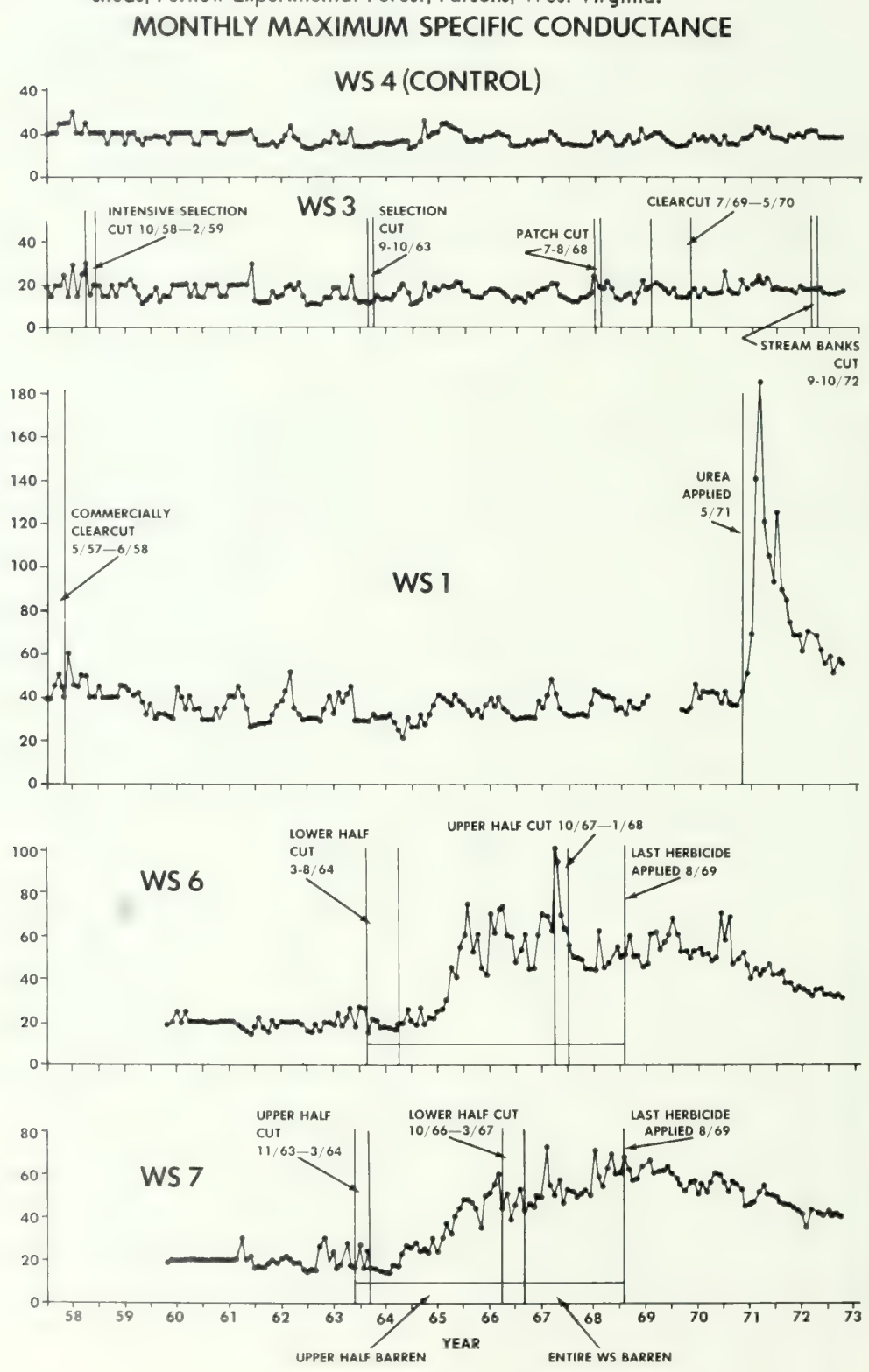
Maximum growing-season stream temperatures for watershed 6 averaged about 10°F higher than those on the control watershed, while watershed 7 averaged about 4°F higher. The marked difference between the results of deforesting and herbiciding the lower halves of watersheds 6 and 7 reflect orientation and the harvesting techniques employed. In south-facing watershed 6, the trees were felled in such a manner that a minimum of slash covered the stream channel area. In east-facing watershed 7, the reverse was true: the stream was partly covered by a large amount of slash that shaded the channel. By contrast, watershed 3 — with two selection cuttings, a patch cutting, and a complete clearcutting of all but the channel area — showed little or no influence of cutting on stream temperature. This reflects the importance of leaving uncut trees to shade the stream channel if maintenance of cool water is an objective of forest management.

### *Specific Conductance*

Specific conductance indicates, within rather wide limits, the concentration of ionized substances in water. These values give no indication of which ionized substances are present, but any increase or decrease in their concentration will cause corresponding changes in conductivity. Thus specific conductivity can be used to infer chemical changes in the water.

The data show that, on the Fernow Forest, a watershed can be clearcut without producing major increases in the stream's specific conductance (fig. 2, WS 3). Under less carefully controlled clearcutting conditions, the resultant increase in conductivity was short-lived

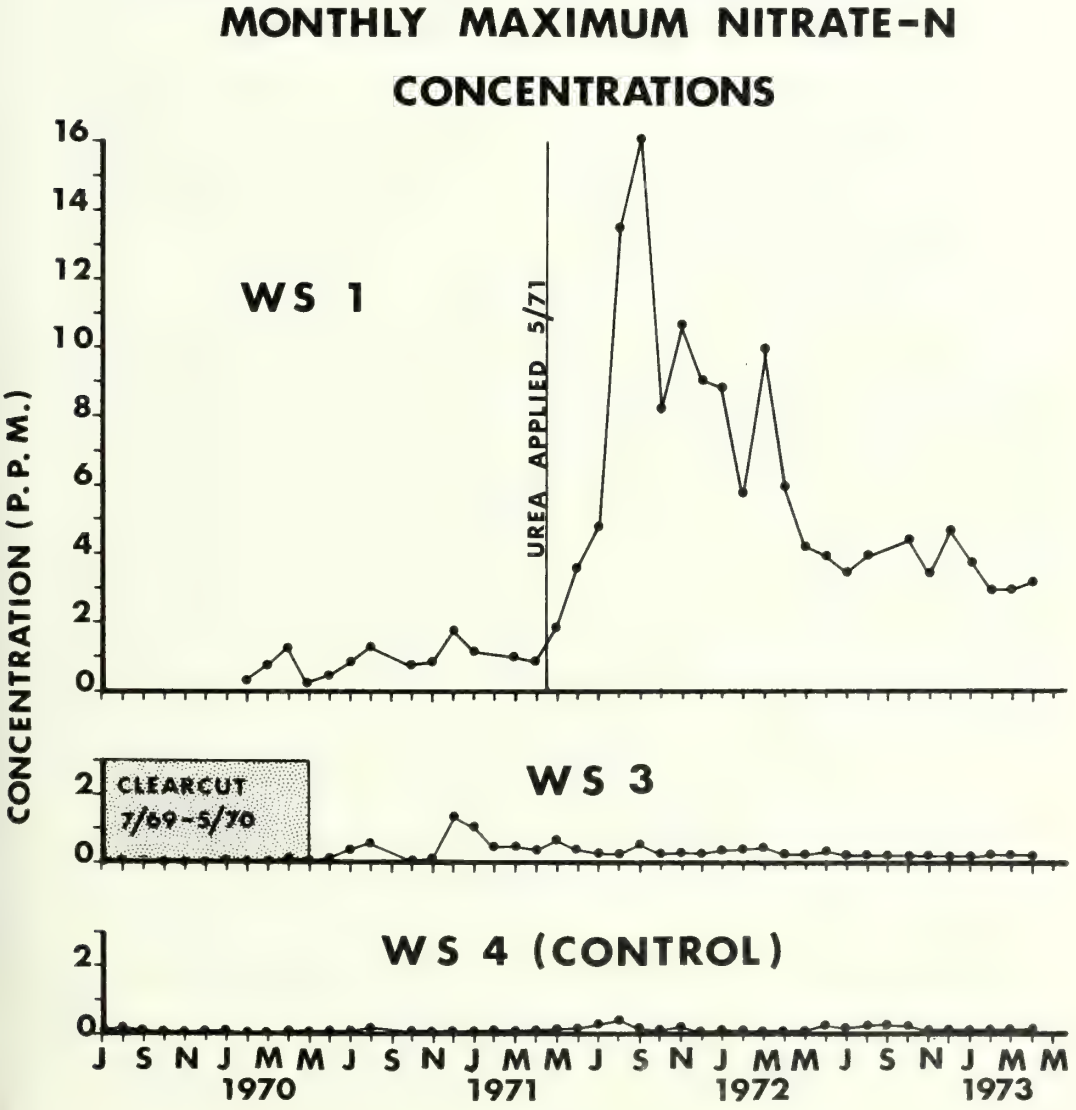
Figure 2.—Monthly maximum specific conductance for selected watersheds, Fernow Experimental Forest, Parsons, West Virginia.



and returned to pre-cutting level as the watershed revegetated (fig. 2, WS 1). Only when we prevented natural regrowth did the streams' specific conductance increase markedly (fig. 2, WS 6 and WS 7). Regrowth and declining specific conductance followed termination of herbicide applications. The major difference between the clearcut and the deforested and herbicided watersheds was prevention of natural revegetation on the latter.

Applying 230 pounds of nitrogen per acre in the form of urea to watershed 1 markedly increased that stream's specific conductance (fig. 2, WS 1). Immediately after application, the specific conductance began to increase, reaching a maximum approximately 6 times higher than normal 4 months after application. Decline has since been steady, and the specific conductance now is approximately 1.5 times the pre-fertilization level.

Figure 3.—Monthly maximum nitrate-N concentrations for selected watersheds, Fernow Experimental Forest, Parsons, West Virginia.



### *pH and Alkalinity*

Timber harvesting had little effect on pH and methyl orange alkalinity levels. The watershed 1 treatment increased the mean pH from about 6.1 to 6.4 and the alkalinity about 2 ppm *(Reinhart et al. 1963)*. The other treatments had even smaller effects.

### *Nutrients*

Of the twelve nutrients studied, nitrate-N usually is considered most significant to water quality. Our limited data suggest that Fernow watersheds can be clearcut without appreciably increasing nitrate-N concentration in the streams (fig. 3, WS 3). Another study showed that fertilizing a watershed with urea can cause a marked increase in the stream's nitrate-N concentration (fig. 3, WS 1). Even so, this stream's nitrate-N concentration remained well below the U.S. Public Health's drinking-water limit of 10 ppm, in 811 of 829 samples analyzed during the first year after application.

Nitrate-N levels for watershed 7 have shown a steady decline from about 5 ppm, in January 1971 when determinations were begun, to the present level of about 2 ppm. Watershed 6 shows a similar trend but with corresponding concentrations between 0.5 and 1 ppm lower. Levels of other nutrients were little affected by clearcutting *(Aubertin and Patric 1972)*. However, after urea fertilization, the concentrations of calcium, magnesium, sodium, and potassium increased slightly *(Aubertin and Smith 1972)*.

## WATER YIELD INCREASES

### *Amount*

Equations developed during the calibration period *(Reinhart et al. 1963)* provided a means to demonstrate streamflow changes after forest cutting. Growing-season increases in water yield from the Fernow watersheds generally have been proportional to the severity of cutting (fig. 4). The lightest cutting that produced a statistically significant increase was on watershed 5. There, 20 percent of the basal area was cut; average timber volume removed was 3,690 board feet per acre. Ten years later, a similar cut on watershed 5 removed 13.7 percent of the basal area or 2,453 board feet per acre, but failed to produce a significant yield increase.

The effects of other variables such as tree size, species composition, and spatial arrangement of the cutting have not been tested on the Fernow watersheds. The largest yield increase occurred after watersheds 6 and 7 were deforested and treated with herbicides to prevent forest regrowth. We suspect that increased evapotranspiration after fertilization contributed to the rather large decrease in streamflow on watershed 1 during the 1972 growing season. This decrease will be examined more closely in the near future.

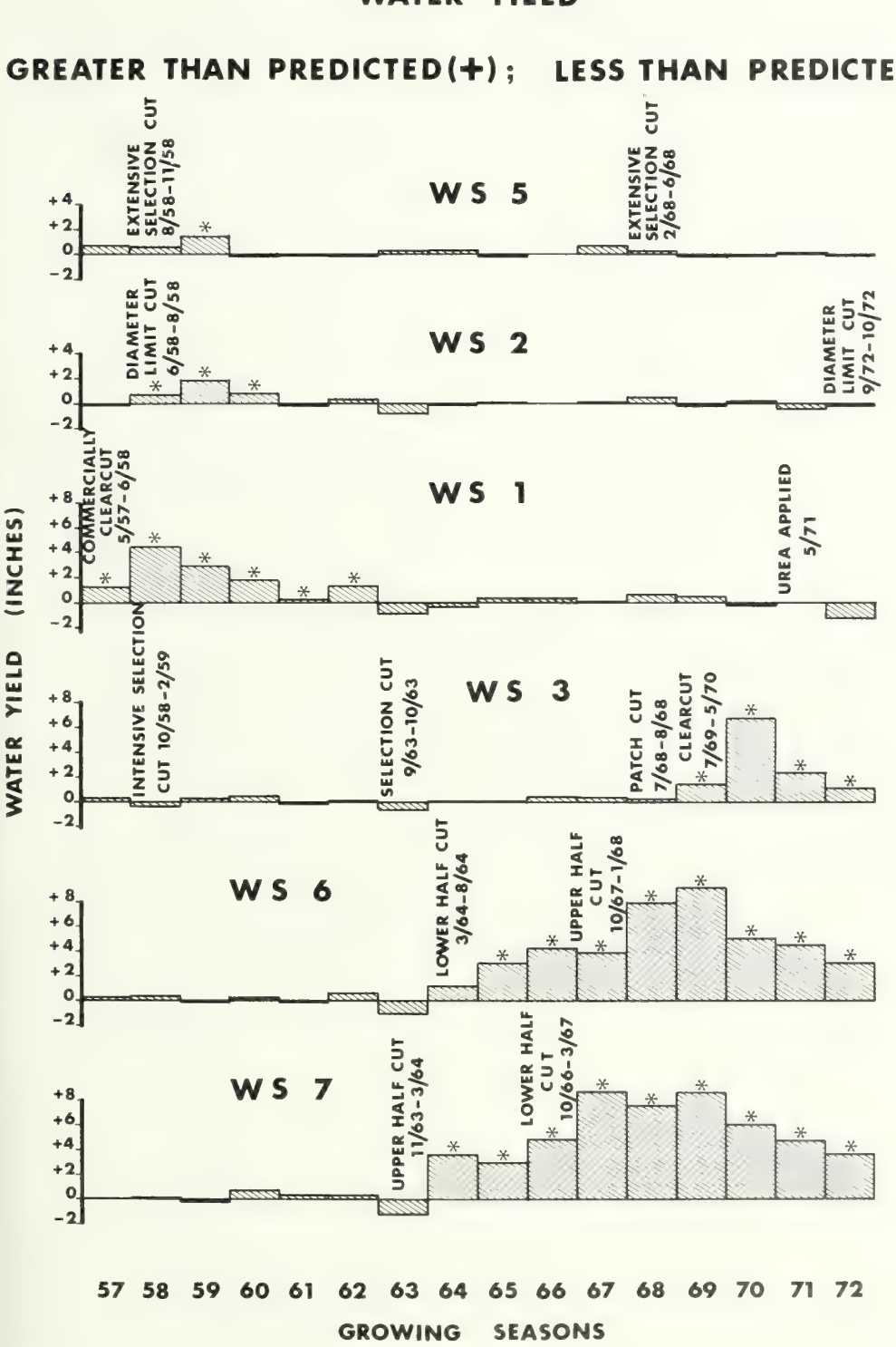
### *Timing*

When a substantial part of the forest was cut early in the growing season, significant increases in water yield were obtained at that time, but the largest increases usually occurred during the first growing season after treatment. Largest increases always occurred from July to November. Dormant-season responses were variable, usually less than half of those obtained during the growing season. The most consistent and usually the largest dormant-season yield increases occurred in November and December.

### *Longevity*

The duration of yield increases also varied with severity of cutting. Streamflow increases resulting from cutting on the Fernow Forest have returned rather rapidly to pre-treatment levels (fig. 4). Yield increases obtained by partial cutting (watersheds 2, 3, and 5) were never significant for more than 2 years.

Figure 4.—Effects of treatments on water yields. Deviation of water yields from amounts predicted for selected watersheds, Fernow Experimental Forest, Parsons, West Virginia.



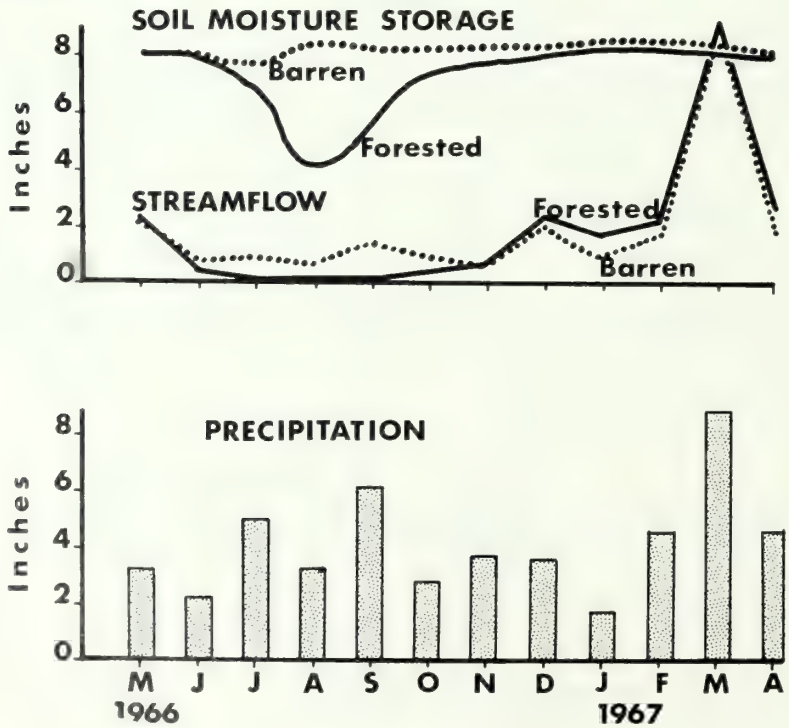
Yield increases after clearcutting lasted 6 years on watershed 1 and 5 years on watershed 3. Clearcutting with herbiciding (watersheds 6 and 7) produced the longest lasting increases. Three years of regrowth have reduced yield increases about two-thirds on watersheds 6 and 7, where revegetation has been slower. After three growing seasons, woody vegetation comprised only 15 percent of the ground cover, most of it of seed origin as opposed to other watersheds where regrowth was primarily of sprout origin. Regrowth from old root systems would at least initially be expected to better exploit soil moisture. The faster recovery of watershed 6 may relate to the fact that the upper half of this watershed was herbicided for only 2 years and that much of the vigorous regrowth there is of sprout origin.

***Stormflow***

The effects of heavy cutting on stormflow have been variable *(Reinhart 1963)*. Generally, growing-season peaks increased; dormant-season peaks were unaffected. Patric *(1973)* reported that instantaneous peak flows were increased during small storms when watersheds 6 and 7 were barren, but this peak effect was minor in large storms and in all storms during the dormant season.

Troendle *(1970a)* noted that timber-harvesting generally extended periods of high flow and shortened periods of low flow. The effects of treatment were greatest on low flows. Deforestation increased the duration of streamflow on watersheds 6 and 7. Streams draining these watersheds had dried up periodically when the watersheds were fully forested; during deforestation, flows

Figure 5.—Soil moisture-streamflow relationships. Upper, soil moisture and discharge from forested and barren watersheds. Lower, precipitation.



in both watersheds were never less than 0.3 cfsm *(Patric and Reinhart 1971)*.

### *Soil Moisture Influences*

Soil-moisture depletion on the Fernow provides an insight into streamflow response to treatment. There was a close correlation between streamflow and moisture content in the upper 2 feet of soil *(Troendle 1970b)*. During the growing season, up to a 4-inch soil-moisture deficit has been recorded on forested areas on the Fernow Forest (fig. 5). Substantial reduction of water normally lost by transpiration and interception maintained soil moisture at higher levels during the growing season on barren or recently cut areas (fig. 5).

Streams draining the wetter soils on barren or recently cut watersheds are more responsive to precipitation than those draining the drier, forested areas. After soil became recharged, streamflow responses on treated and forested areas were similar except for small differences due to snowmelt. Soil-moisture measurements indicated that the relatively shallow soils on the Fernow Forest usually are recharged by January and remain so until May.

## DISCUSSION

Perhaps the most important finding to emerge from the Fernow research is that timber-harvesting with well-planned, well-constructed, and well-maintained road systems simply does not damage water resources. The severity of cutting has little effect on water quality when enough trees are left to shade stream channels. Thus it is possible to produce potable water from forest land and also manage for other uses such as timber production, recreation, and wildlife habitat.

The relatively short-term effects of removing vegetation and the difficulty of controlling revegetation govern attempts to manage forest land for water. Experience on the Fernow Forest indicates that water-yield increases will not be maintained merely by periodically harvesting merchantable forest products. Increased water yield, resulting from the lightest cut that produced a significant increase of water yield on the Forest, lasted only 1 year. In other words, this cutting would have to be repeated annually to maintain the flow increase. Yet, silviculturally speaking, this heavy a cutting requires at least a 10-year cutting cycle even on the most productive sites. In the Appalachians, it requires at least 20 years for a tree to reach merchantable size. In many areas where there is no market for small products, 40 years would be a more realistic figure.

Economically, the difference between manipulating merchantable and unmerchantable vegetation is very great. No additional costs above those normally associated with harvesting forest products are incurred when it is silviculturally desirable to cut merchantable trees; under these circumstances, increased streamflow can be considered a free by-product. Removal of unmerchantable trees to improve streamflow is an entirely different matter. The vigorous regrowth characteristic of the Appalachians is extremely difficult and costly to control. Aerial application of herbicides would seem to be the only practical way to maintain control of vegetation on areas large enough to appreciably influence water yields. The acceptance of this practice by a public that is concerned about environment is indeed highly questionable.

## CONCLUSIONS

- Given current market values, it is not practical to manage forest land for both sustained water yield increases and merchantable timber products.
- Forest land can be managed for a variety of uses without impairing water quality if these uses are regulated intelligently.

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# EFFECTS OF MANAGEMENT PRACTICES ON WATER QUALITY AND QUANTITY: BALTIMORE, MARYLAND, MUNICIPAL WATERSHEDS

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*ABSTRACT.* To complement its water-management program, the City of Baltimore, with the assistance of the Northeastern Forest Experiment Station, is conducting research on the effects of vegetation management on water yield and quality. Three small watersheds, ranging in size from 22 to 38 acres, have been selected for this purpose. Two of the watersheds, formerly in open land except for hardwoods along the riparian zones, were reforested 17 years ago with white and loblolly pines. Converting the open land to a pine forest caused a substantial reduction in water yield. The effects of removing riparian-zone vegetation and also thinning the young pine plantations are evaluated from the viewpoint of the municipal watershed manager.

THE CITY OF BALTIMORE owns 17,580 acres of watershed land surrounding its three water-supply reservoirs: Loch Raven, Prettyboy, and Liberty. The reservoirs have a combined surface area of 7,000 acres and are located to the north and northwest of the city in Maryland's Piedmont region. Management of the 24,580 acres of land and water is the responsibility of the Baltimore Division of Water Supply.

The watershed lands were acquired between 1910 and 1955. At first, management practices were limited to fire protection and planting a protective forest cover on abandoned land around the reservoirs. There are approximately 4,100 acres of plantations on watershed property. The earliest of these plantations date back to 1912, but most were established in the early 1950s.

The species planted are — in descending order of acreage — white pine, loblolly pine, red pine, Scotch pine, shortleaf pine, and Norway spruce. Small areas of hardwood species such as red oak, yellow-poplar, and black locust have also been planted.

Timber cutting on watershed lands began in 1948 when the area for Liberty Reservoir was cleared. A policy of multiple-use management was adopted at that time. The objectives of the new policy were to plan, manage, and super-

vise a coordinated conservation program of forest, soil, and water resources, for water production and protection, timber-growing, improvement and utilization of timber resources, and recreation. Details of the current management program have been given by Mr. Hartley *(1975)* at this Symposium.

## COOPERATIVE RESEARCH PROGRAM

### *Experimental Watersheds*

To complement its land-management program, the City of Baltimore is conducting, with the assistance of the Northeastern Forest Experiment Station, research on the effects of vegetation management on water yield and quality. Three small watersheds near Liberty Reservoir, ranging in size from 22 to 38 acres, were selected for this purpose. Topography is hilly. Streamflow is measured by 120° v-notch weirs mounted on weir boxes. The percentage of precipitation that leaves the watersheds as surface streamflow is considerably less than from small mountainous watersheds in the East, especially in the dormant season.

Watersheds 1 and 2, formerly in open land (grass with pockets of brush) except for hardwoods along the riparian zones, were reforested in 1955-56 with white and loblolly pines at approximately a 5 x 6 foot spacing. Watershed 3 contains a stand of mixed hardwoods and will be used to evaluate the effects of Baltimore's normal timber-harvesting methods on water yield and quality in a future study. During the study there were short periods when streamflow had to be estimated because of weir-box leakage. A portion of the streamflow from watershed 3 was found to be bypassing the weir box during the early part of this project, so it was not used in this analysis.

### *Soils*

Soils of the Manor series predominate on the watersheds. The Manor soils range from loam to silt loams and gravelly loams and are somewhat excessively drained. Both surface and subsurface soils are very friable. Underlying the subsoil is a very friable, highly micaceous material that can store a large amount of moisture and is easily penetrated by roots. Depth to bedrock ranges from 6 to more than 20 feet. These soils have moderate to high available moisture capacity. Because the Manor soils are so micaceous, they are highly susceptible to erosion *(Matthews 1969)*.

Soils of the Glenelg series are second in importance on the experimental watersheds. They are well drained and the subsoil is underlaid by a friable, micaceous material. Available moisture capacity is moderate to high. The subsoil is rather thin, and sticky when wet. Depth to bedrock ranges from 4 to 10 feet *(Matthews 1969)*.

Soils along the stream channels are of the Delanco series, and these are moderately well drained. They have a high available moisture capacity. The depth to bedrock is 6 to 20 feet. The lower part of the subsoil is mottled, indicating that the soils are wet and poorly aerated at least part of the year *(Matthews 1969)*.

## EFFECTS OF REFORESTATION ON WATER YIELD

### *Method of Analysis*

To evaluate the effects of reforesting an open-land watershed, a single-watershed calibration method of analysis was used. Water yield of watershed 2, while in an open-field / seedling stage (1958-62), was compared with yield during a period after the tree crowns had closed (1966-71). Tree heights ranged from 12 to 32 feet in this latter period. A precipitation index was selected as the

independent variable to predict what water yield would have been had the trees not been planted. Differences between predicted and measured streamflow were then computed to quantify the effects of reforestation. Water-yield calculations for growing season (May-October), dormant season (November-April), and hydrologic year (October-September) were made.

Correlations between precipitation and streamflow were weak for both seasonal and annual values. Thus the influence of antecedent precipitation was investigated. Various antecedent precipitation periods were tested. It was determined from the correlations that a significant carryover effect from antecedent precipitation existed for both annual and seasonal periods. This was attributed mainly to the deep soils with their large water-storage capacity.

Therefore, annual and seasonal precipitation values, adjusted for the carryover effect by adding in antecedent precipitation (forming precipitation indexes), were used in the prediction equations. The strongest correlations were obtained by using a 12-month antecedent period for the seasonal water-yield prediction equations and a 6-month antecedent precipitation period for the annual prediction equation.

### *Results*

Seasonal and annual streamflow from reforested watershed 2 were much less after crown closure than under conditions prevailing at the time of tree planting (table 1). The estimated decrease in annual water yield averaged 8.77 inches during the period 10 to 15 years after planting and ranged from approximately 5½ to 12 inches. Almost 60 percent of this decrease occurred during the dormant season. The average reduction in water yield is equivalent to 238,000 gallons of water per year per acre reforested.

Table 1.—Estimated decrease in water yield from converting an open-land watershed to pine forest.

| Years after tree planting | Water yield reduction[1] | | |
|---|---|---|---|
| | Annual | May-Oct. | Nov.-Apr. |
| | Inches | Inches | Inches |
| 10 | 5.44 | 2.27 | 4.79 |
| 11 | ([2]) | ([2]) | ([2]) |
| 12 | 11.97 | 5.68 | 6.28 |
| 13 | 10.79 | 4.42 | 7.79 |
| 14 | 5.92 | 2.47 | 4.17 |
| 15 | 9.73 | 3.07 | 2.91 |
| Average | 8.77 | 3.58 | 5.19 |

[1]Seasonal reductions may not equal annual reductions because prediction equations are independently derived.

[2]Stream-gaging station out of service.

Evapotranspiration differences of the vegetation covers and increased interception losses (especially during the dormant season) are major causes of the decrease in streamflow. They result in greater soil moisture depletion under the forest cover and create larger moisture deficits than would normally occur under open field conditions. To satisfy the deficits, a larger proportion of precipitation during the dormant-season recharge period goes into soil moisture storage and is not immediately available for streamflow.

## EFFECTS OF VEGETATION REMOVAL ON WATER QUANTITY

Several cutting treatments have been conducted in watershed 1 since the development of the tree cover, in addition to a vegetation conversion in the riparian zone. The treatments are summarized in table 2.

### *Methods of Analysis*

Two approaches were used to evaluate the effects of the treatments on water yield. A single-watershed calibration was made for watershed 1 as in the previous analysis for watershed 2. Differences between the streamflow reductions on the two watersheds were used as esti-

Table 2.—Vegetation manipulation on Watershed 1

| Years after tree planting | Watershed treatment |
|---|---|
| 10 | Hardwood vegetation along the main and secondary channels cut back from streams a distance of 30 to 125 feet (fig. 1). |
| 11 | Mechanical removal of stumps. Cut area seeded with grass. |
| 12 | Grass cover in riparian area mowed. |
| 13 | Pine plantation thinned except for 10 percent of stand on upper end of watershed. Every other row was removed, producing 165 cords of wood. Stand not opened up greatly due to closeness of original planting. Grass cover in riparian area mowed. |
| 14 | Grass cover in riparian area mowed. |
| 15 | Remainder of pine plantation thinned by removing every other row. Remaining hardwoods along the fringe of the riparian zone were cut. Grass cover in riparian area mowed. |

mates of the treatment effects on watershed 1.

In addition, a control-watershed approach was used, utilizing watershed 2 as the control. Streamflow relationships between the two watersheds during a 5-year calibration period (1958-62) were used to develop equations for predicting the streamflow of watershed 1 from the measured streamflow at watershed 2. After modifying the vegetation cover (table 2), differences between predicted and measured streamflow for watershed 1 were used for quantifying vegetation treatment effects on water yield.

In experiments of this type, all watersheds are usually in a fully forested condition at the start of the calibration period. In this case the calibration began when both watersheds were in an open-field/seedling stage. The results of this analysis are based on the supposition that the streamflow calibration relationship between the watersheds will not change significantly as the forest stand develops.

### *Results*

Effects of the vegetation treatments on annual water yields are presented in table 3. Yield increases, as estimated by the single-watershed calibration analysis, were about three times those estimated by the control-watershed analysis. In the control-watershed analysis only the 3.31 inch increase was statistically significant. The size of the increases for both methods was strongly influenced by annual precipitation, the larger increases being associated with years of high precipitation.

Cutting forest vegetation in the riparian zone and converting this area to grass (fig. 1) increased watershed streamflow an average of 1 to 3 inches. The grass was mowed during the summer to reduce the transpiration surface and keep interception losses to a minimum. With equations developed by Corbett and Crouse *(1968)*, adapted to Baltimore conditions, it was estimated that average grass interception losses would be reduced by 1.6 inches in the conversion zone by keeping the grass stand mowed.

The effects of thinning the pine stand (fig. 2) did not appear to contribute any additional water. Roots of trees remaining on the thinned area still were apparently occupying the site fully so that the trees could utilize most of any additional soil moisture made available. In addition, the rapid invasion of black locust and Japanese honeysuckle in the thinned stand contributed to moisture losses.

Low precipitation during this period may also have been a factor. Removing the remaining hardwoods along the fringe of the riparian zone (right side of stream channel in figure 1) seems to have had a substantial effect on enlarg-

Table 3.—Estimated increases in annual water yield following Watershed 1 treatments

| Years after tree planting | Annual precipitation | Based on control-watershed analysis | Based on single-watershed calibration analysis |
|---|---|---|---|
| | Inches | Inches | Inches |
| 10 | 35.04 | 0.98 | 2.66 |
| 11 | 43.26 | (1) | (1) |
| 12 | 41.18 | 1.10 | 4.03 |
| 13 | 34.13 | .03 | 2.22 |
| 14 | 36.49 | .67 | 1.83 |
| 15 | 54.29 | 3.31 | 4.80 |

[1]Stream-gaging station out of service.

Figure 1.—Initial riparian cut on watershed 1. Hardwood vegetation to the right of the stream channel was removed in a later cut.



Figure 2.—Removing 50 percent of the pine stand by thinning every other row of trees did not open the stand severely.



ing the water yield increase. These trees were removed from an area that contains a spring and is generally wet most of the year. Above-average rainfall probably contributed to the size of this increase. The observed water yield increases occurred mainly during the summer-fall period.

## EFFECTS OF VEGETATION REMOVAL ON WATER QUALITY

### *Erosion*

After the riparian-zone vegetation was cut, a dense stand of hardwood sprouts and herbaceous species began to develop. This regrowth was controlled by mechanical removal of stumps and seeding the area to grass.

Turbidity samples were taken only once a week when the instrument charts were changed. As a result, stormflow turbidities could not be defined. Stream turbidity increased up to 30 times that of the control watershed after cutting the riparian vegetation. Erosion was more severe after the stumps were pulled. Storms caused a great amount of soil movement from the disturbed area, filling the weir box with eroded material.

The next year, after establishment of a dense grass cover, average stream turbidity was 2.4 ppm. Average turbidity on the control watershed was 1.4 ppm for the same period. There was no increase in turbidity from the thinning operation or removal of hardwood vegetation located away from the stream channel.

A debris survey was made after tropical storm Agnes in 1972. Eleven inches of the 14 inches of storm rainfall fell in 1 day at a uniform intensity (about 0.5 inch per hour). Eroded material deposited at the mouths of the watersheds was related primarily to depth of channel. The greatest amount of debris was produced on watershed 3, although it has a complete hardwood forest cover. Streambanks in this watershed are considerably higher than those in the other watersheds due to much stream cutting in the past. The channel may not yet be entirely stable. Most of the erosion occurring on the watersheds was from streambank cutting and channel slumping.

### *Stream Temperature*

Summer stream temperatures were significantly increased after removal of the riparian forest cover. Average summer maximum water temperatures have been increased 8° to 13.6°F since the initial cut. Minimum stream temperatures were increased by 1° to 2°F during the summer. Maximum water temperatures over 80°F were recorded several times, especially during periods of extremely low flow.

## CONCLUSION AND DISCUSSION

Many municipal watershed managers have improved the quality of their raw water supply by reforesting abandoned and eroding lands. Part of the cost paid for this improvement is the reduction in water yielded from these areas. Our study indicates that converting an open-land watershed to a young pine forest caused a decline in water yield of 238,000 gallons of water per year per acre reforested. This is equivalent to a layer of water almost 9 inches deep over the entire watershed.

Conversion of riparian-zone vegetation from hardwoods to grass increased watershed streamflow about 2 inches. The conversion was accompanied by serious erosion problems, as mechanical methods rather than herbicides were used in controlling sprout regrowth. Erosion in the channel areas, even on forested watershed 3 during large storms, showed how sensitive this portion of the watershed is. Protection of the stream channel in any management

program should be a primary concern of the watershed manager. Any accelerated erosion on upstream watersheds will speed up the siltation of reservoirs, reducing their water-storage capacity.

Thinning the pine stand by removing every other row of trees provided $4,000 of gross income but had little effect on water yield. The remaining trees were able to utilize any additional soil moisture during 2 years of below normal precipitation. Also, the increased light stimulated the growth of Japanese honeysuckle and black locust in the pine stand contributing to soil moisture losses. Honeysuckle had encroached well into the crowns of the pines a year after the thinning. Dragging a dozer blade between tree rows pulled a substantial amount of honeysuckle out of the tree crowns and uprooted many of the black locust. Tight crown closure increased shading and has prevented recurrence of this problem.

In situations where municipal ownership of watershed land is substantial, vegetation management can have a significant influence on the amount of water yielded to a reservoir system. In such cases vegetation conversion and planting programs should be carefully evaluated. Establishment of a mixed hardwood forest on an open-land watershed would not reduce water yield as much as a pine forest *(Swank and Minor 1968)*. Open fields on watershed property would benefit both water yield and wildlife.

Where only a small portion of a watershed is municipally owned, water-yield considerations will be of less importance unless cooperation with other landowners for a coordinated vegetation-management program can be secured. Under these circumstances, high priority should be given to vegetation management for derivation of municipal income along with recreation and aesthetic considerations. Protection of water quality in the reservoir system and maintaining reservoir capacity are of primary importance in both cases.

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# EFFECTS OF MANAGEMENT PRACTICES ON WATER QUALITY AND QUANTITY: THE PENN STATE EXPERIMENTAL WATERSHEDS

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*ABSTRACT.* The results of phase one and phase two of a three-phase clearcutting experiment on a 106-acre watershed in central Pennsylvania are reported. Phase one involved the removal of the vegetative cover on 21.3 acres of the lower-slope portion of the watershed. Phase two consisted of clearcutting an additional 27.0 acres on the middle-slope portion of the watershed. The effects of these treatments on water quality, quantity, and streamflow timing have been evaluated. Water quality parameters investigated include turbidity, temperature, acidity, and selected nutrients. Water quantity data were evaluated on monthly, seasonal, and annual bases. Quickflow volume, instantaneous maximum peak, time to peak, time of recession, and antecedent flow rate of storm hydrographs were also investigated.

WITH INCREASING population growth and industrialization, greater demands are being placed on our Nation's water supplies. An increasing number of communities have experienced problems in obtaining a sufficient supply of high-quality water for both domestic and industrial use during the past 10 years.

In Pennsylvania, forests cover more than half of the land area and hence receive a large portion of the state's precipitation. Moreover, since these forest areas generally occupy mountainous lands, they serve as collection basins for many of the state's municipal water-supply systems and exert a major influence on the continuity and quality of streamflow. Thus one approach to solving our water problems depends upon research directed towards augmenting water supplies through forest-management practices.

To evaluate management effects on water-supply parameters, the Leading Ridge Experimental Watershed Research Unit was established. It is part of a cooperative research project of The Pennsylvania State University, The Pennsylvania Department of Environmental Resources, Bureau of Forestry, and the Northeastern Forest Experiment Station, U.S. Forest Service.

## DESCRIPTION OF WATERSHED UNIT

The Leading Ridge Watershed Research Unit, located in the ridge and valley province of central Pennsylvania, consists of three adjacent watersheds, which are 303, 257, and 106 acres in area. These watersheds are representative of approximately 10 million acres of Pennsylvania forest, much of which lies within established municipal watershed boundaries.

On all three watersheds, modified broad-crested Trenton weirs with a sharp-crested, 90-degree, V-notch in the center were used to measure stream discharge. Each weir is 30 feet wide and has a total capacity of 117 cubic feet per second (fig. 1). The watersheds all have a southeastern aspect; they range in elevation from 900 to 1,450 feet. Mean slopes are 12.1 percent on the treated watersheds and 17.3 percent on the control.

The watersheds are underlain by three major geological formations. The Rose Hill shale formation, which underlies most of the lower slopes of the watersheds, is approximately 700 feet thick. The upper part of the lower slope, middle slope, and most of the upper slope is underlain by Castanea sandstone having a thickness of approximately 500 feet, while Tuscarora quartzite underlies the ridge top.

Most of the soils are residual, having developed in place through the weathering of the underlying strata. A soil survey resulted in the classification of nine major soil types. Soils on the lower slopes are primarily silt and stony loams that are well-drained and have a high moisture-holding capacity. The middle and upper slopes are classified as cobbly and stony loams, which are also well-drained. Rough, stony land covers the ridge top. The average depth of the soil mantle is 66 inches. Total water-holding capacity is 28 area-inches.

The vegetative cover consists of an uneven-aged coppice forest of oak, hickory, and maple. Predominant species are white oak *(Quercus alba* L.), red oak *(Q. rubra* Asche), and black oak *(Q. velutina* Lamb) on the lower and middle slopes. On the upper slopes and ridge top, the dominant species are chestnut oak *(Q. prinus* L.), with red oak, black oak, and pitch pine *(Pinus rigida* Mill) as associates. The subordinate layer consists of dogwood (Cornus florida L.), red maple *(Acer rubrum* L.), and witch hazel *(Hamamelis virginiana* L.).

Figure 1.—Stream-gaging station at Leading Ridge Watershed 1. This fully forested watershed provides base data for evaluating the effects of cutting treatments on streamflow.



## METHOD

Since completion of a 7-year calibration period two phases of a three-phase experiment, involving the complete clearcutting of the 106-acre watershed, have been implemented (fig. 2). The purpose of each of clearcutting is to determine the effects of removing forest cover from each area (lower slope, mid-

Figure 2.—Aerial view of Leading Ridge Watershed 2. The treatment areas are roughly separated by the road through the center of the clearcut. The first treatment area is the darker section below the road; the second treatment area is the lighter section above the road.



dle slope, and upper slope and ridge top) on water yield and quality.

Phase one (during the winter of 1966-67) involved the removal of 53,878 cubic feet of timber on 21.3 acres of the lower-slope portion of Leading Ridge Watershed 2 (table 1). This clearcut was essentially a complete riparian cut, since all of the main stream channels on the watershed are located within its boundaries. Phase two consisted of clearcutting an additional 27.0 acres on the middle-slope portion of the watershed during the winter of 1971-72. Total volume removed was 87,476 cubic feet (table 1). To reduce the amount of soil disturbance, cutting was limited to times when the ground was frozen. Skid trails and logging roads were carefully located to prevent erosion. All slash was removed from the stream channel and lopped and scattered.

After completion of phase one, road areas and log-loading areas were seeded with a mixture of annual and perennial ryegrass along with pulverized limestone and 10-10-10 fertilizer to facilitate rapid revegetation and reduce erosion. During the summers of 1967, 1968, and 1969, the clearcut area was sprayed with a mixture of 2,4,5-T and 2,4-D herbicides (Amchem Weedone) to control stump sprouts. The application weight was 2 pounds of acid equivalent per acre. No seeding or spraying followed the completion of phase two (fig. 3).

Table 1.—Treatment characteristics of Leading Ridge Watershed 2

| Characteristic | Treatments | | |
|---|---|---|---|
| | Lower slope | Middle slope | Total |
| Area cut (acres) | 21.3 | 27.0 | 48.3 |
| Basal area (square feet) | 2,103 | 2,398 | 4,501 |
| Basal area per acre cut (square feet) | 99 | 89 | 94 |
| Volume cut (cubic feet) | 53,878 | 87,476 | 141,354 |
| Volume per acre cut (cubic feet) | 2,119 | 2,015 | 2,067 |



ure 3.—Rapid regrowth of vegetation on two clearcut portions of Leading Ridge atershed 2 prevented serious erosion. The er slope is now mainly in grass and other baceous vegetation. The middle slope ntains hardwood sprouts and grasses.

The calibration period started 1 May 1959 and ended 31 December 1966. The treatment period for phase one lasted from 1 January to 30 April, 1967, and the after-treatment period from 1 May, 1967 to 31 October, 1971. The treatment period for phase two lasted from 1 November, 1971 to 30 April, 1972. The after-treatment period involving both clearcuts was 1 May, 1972 to 30 April, 1973.

## RESULTS AND DISCUSSION

### *Water Quality*

*Turbidity.* — Routine turbidity samples were collected three times a week from the control and treated watersheds. Storm samples were taken during storm periods when streamflow was at or near peak discharge. Samples were analyzed with a Hellige Turbidmeter.

The effect of both lower- and middle-slope treatments on streamflow turbidity is presented in table 2. Results indicate that the impact of timber removal on streamflow turbidity was greatest during and immediately after the lower-slope cutting. Maximum storm turbidity during logging was 550 ppm on the treated watershed. Most of this turbidity, which could be traced to scarified log-loading areas, decreased immediately after completion of logging. Average storm turbidity on the treated watershed decreased from 196 ppm during logging to 11 ppm the first year after logging, and ranged from 3 to 13 ppm over the last four after-treatment years. On the control watershed, storm turbidity never exceeded 25 ppm during the logging period and consistently averaged less than 5 ppm during the last four after-treatment years.

Nonstorm turbidity samples were not measured during the lower-slope logging period. However, during the 4-year period after completion of logging, nonstorm turbidity averaged only 2 ppm on

Table 2.—Effect of treatments on stream water turbidity during and after logging
[All values are in ppm]

| Period | Treated watershed | | | | Control watershed | | | |
|---|---|---|---|---|---|---|---|---|
| | Storm | | Nonstorm | | Storm | | Nonstorm | |
| | Ave. | Max. | Ave. | Max. | Ave. | Max. | Ave. | Max. |
| LOWER-SLOPE CLEARCUTTING | | | | | | | | |
| During logging[1] | 196 | 550 | — | — | — | <25 | — | — |
| After treatment | 9 | 119 | 2 | 24 | 3 | 29 | 1 | 17 |
| MIDDLE-SLOPE CLEARCUTTING | | | | | | | | |
| During logging[2] | — | — | 2 | 11 | — | — | 2 | 7 |
| After treatment | 4 | 13 | 1 | 6 | 2 | 7 | 1 | 4 |

[1]Nonstorm turbidity was not measured.
[2]Insufficient storm data.

the treated watershed and 1 ppm on the control. Maximum nonstorm turbidity during this period was 24 ppm on the treated watersheds and 17 ppm on the control watershed.

An insufficient number of storms occurred during the middle-slope timber-harvest operation to determine effects on stream turbidity. However, nonstorm turbidity measurements indicate that the effects of the middle-slope cutting on stream turbidity were considerably less than those from the lower-slope cutting (table 2). Nonstorm turbidity measurements made during this period averaged only 2 ppm on both the treated and control watersheds. Maximum nonstorm turbidity measured was 11 ppm on the treated watershed and 7 ppm on the control watershed.

Storm turbidity samples taken the first year after completion of the middle-slope logging averaged 4 ppm on the treated watershed and 2 ppm on the control watershed. Maximum storm turbidity during this period was 13 ppm on the treated area and 7 ppm on the control. Nonstorm turbidity the first year after completion of logging never exceeded 6 ppm and averaged only 1 ppm on both the treated and control watersheds.

*Water temperature.*—After the lower-slope cutting, summer water temperatures on the treated watershed were considerably higher. Average summer (June, July, and August) maximum water temperature increased 7°F (61 to 68°F) in comparison to the control watershed. Mean water temperature increased 4°F (58 to 62°F) during the same period. Minimum water temperatures during the three summer months were generally unchanged as a result of treatment.

The effects of both clearcuttings on stream temperatures were essentially the same as those observed after the lower slope clearcutting. Average summer maximum water temperature on the treated watershed was 8°F (66 to 74°F) higher than on the control watershed. The highest average monthly maximum water temperature of 77°F, an 11°F increase over the average monthly maximum water temperature on the control watershed, was recorded in July. Mean summer water temperature was 4°F (61 to 65°F) higher on the treated area; minimum water temperatures remained unchanged.

*Acidity.* — Cutting the lower- and middle-slope parts of the watershed had

little if any effect on acidity expressed as pH. The average pH on both treated and control watersheds during the calibration period was 7.1. During the lower-slope after-treatment period, pH on both watersheds averaged 6.8. Average-month pH values during this period showed little change. After completion of the middle-slope clearcutting, pH averaged 7.0 on the control watershed and 7.1 on the treated watershed. In general, the water on both treated and control watersheds was slightly alkaline (average pH about 7.2) during the growing season and slightly acid (average pH about 6.8) during the remainder of the year.

*Nutrient concentration.* — Clearcutting had little if any apparent effect on the concentration of the selected elements listed in table 3. This statement is based on the assumption that the nutrient concentrations on the control watersheds represent the uncut condition of the treated watershed and that any major difference would represent a possible treatment effect. This assumption is necessary because no calibration-period data are available and is justified on the basis of the similarities of the vegetation, soils, and geology on the watersheds. Furthermore, analysis of variance revealed that no significant differences existed between the control watersheds or between the control and treated watersheds for any of the elements studied.

The data listed in table 3 are based on 29 water samples collected after the completion of the middle-slope clearcutting during the period May 1972 to June 1973. Because a complete analyses has not been made, the data are not intended to represent exact concentrations of the listed elements. Instead they are presented merely to show that clearcutting did not result in large increases in the concentration of any of the selected elements.

Table 3.—Average nutrient concentration of stream water for treated and control watersheds after completion of middle-slope clearcutting[1]

[All values are in ppm]

| Ions | Control LR-1 | Treated LR-2 | Control LR-3 |
|---|---|---|---|
| $Ca^{++}$ | 3.47 | 3.27 | 3.32 |
| $Mg^{++}$ | .89 | .67 | .73 |
| $K^{+}$ | .58 | .60 | .60 |
| $Na^{+}$ | .95 | .97 | 1.03 |
| $SO_4^{=}$ | 9.08 | 7.95 | 8.11 |
| $NO_3^{-}$ | < .30 | < .30 | < .30 |

[1]Data are based on 29 water samples collected May 1972 to June 1973.

### Water Quantity

*Annual water yield.* — The hydrologic year used was May 1 through April 30 because correlation analyses indicated that this water year had the highest rainfall-runoff coefficient ($r = 0.992$). Annual prediction equations were derived by multiple regression, using runoff from the control watershed and average precipitation as the independent variables.

Findings indicated that the lower-slope clearcutting resulted in increases from 1.22 to 2.87 area-inches in annual water yield during the 5 years after cutting (table 4). This represents an increase of 6.1 to 14.0 inches on an area-cut basis. The treatment effect is also apparent in figure 4, which shows the deviations between actual and predicted annual streamflow during both the calibration and after-treatment periods. With the exception of 1968, it becomes readily apparent from figure 4 that the increase in annual discharge during the lower-slope after-treatment period has remained relatively stable at an average of 2.72 area-inches. This apparent stability is evident despite the fact that since 1969 evapotranspiration has in-

Table 4.—Effect of treatments on annual and seasonal water yield[1]

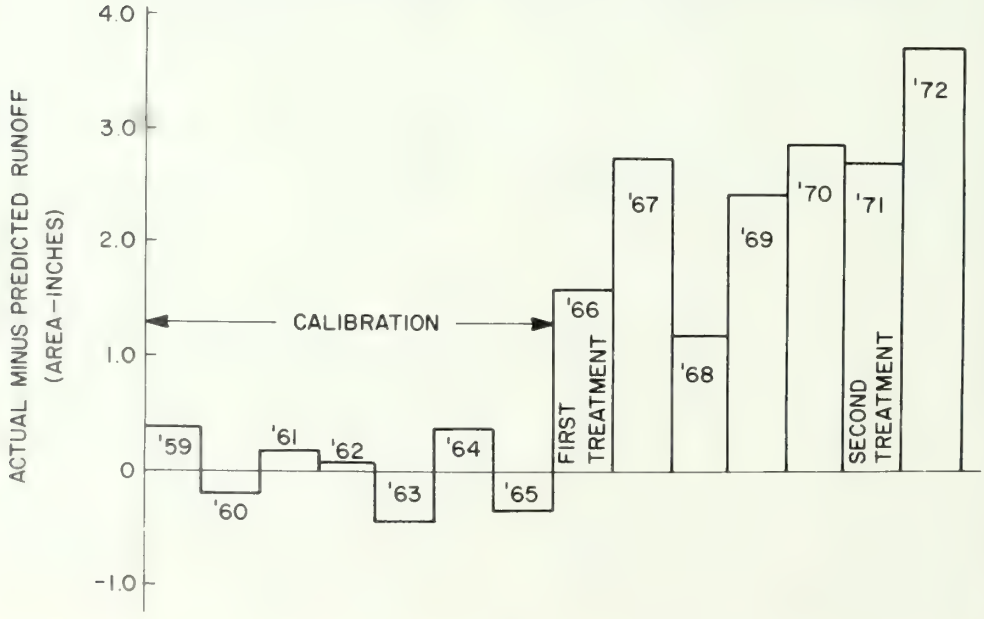
[All values are in area-inches]

| Period | Water yield | | | Precipitation | |
|---|---|---|---|---|---|
| | Predicted | Actual | Change | Annual | Departure from 7-year mean |
| | | | ANNUAL | | |
| 1967 | 15.71 | 18.54 | +2.83* | 37.7 | + 1.0 |
| 1968 | 11.53 | 12.75 | +1.22* | 35.0 | − 1.7 |
| 1969 | 15.40 | 17.82 | +2.42* | 39.2 | + 2.5 |
| 1970 | 21.51 | 24.38 | +2.87* | 45.5 | + 8.8 |
| 1971 | 18.83 | 21.58 | +2.75* | 41.5 | + 4.8 |
| 1972 | 34.98 | 38.74 | +3.76* | 56.2 | +19.5 |
| | | | GROWING SEASON | | |
| 1967 | 6.62 | 8.78 | +0.92* | 25.6 | + 6.6 |
| 1968 | 4.51 | 5.39 | +2.16* | 21.6 | + 2.6 |
| 1969 | 1.71 | 2.63 | +0.88* | 18.9 | − 0.1 |
| 1970 | 2.68 | 4.35 | +1.67* | 24.4 | + 5.4 |
| 1971 | 3.36 | 4.79 | +1.43* | 22.2 | + 3.2 |
| 1972 | 18.76 | 20.25 | +1.49 | 32.0 | +13.0 |
| | | | DORMANT SEASON | | |
| 1967 | 10.81 | 9.76 | −1.05 | 12.1 | + 2.6 |
| 1968 | 7.54 | 7.37 | −0.17 | 13.3 | − 5.6 |
| 1969 | 14.30 | 15.19 | +1.61* | 20.3 | − 4.4 |
| 1970 | 19.02 | 20.03 | +1.01 | 21.2 | + 3.5 |
| 1971 | 16.32 | 16.80 | +0.48 | 19.3 | + 1.6 |
| 1972 | 17.08 | 18.49 | +1.41* | 24.2 | + 6.5 |

*Significant at 5 percent.

[1]Lower-slope after treatment May 1967 through October 1971; middle-slope treatment November 1971 through April 1972; after treatment May 1972 through April 1973.

Figure 4.—Deviations of measured annual streamflow from predicted annual streamflow for the treated watershed during water years 1959-72.



creased as a result of the regrowth of the herbaceous and woody vegetation on the lower slope clearcutting.

However, it should be noted that, since 1969, annual precipitation has been greater than the first three after-treatment years. This increase in the 1970 and 1971 annual precipitation, with respect to the previous after-treatment years, has minimized the effects of increased evapotranspiration. That is, the increases in the 1970 and 1971 annual precipitation may approximate the water loss from regrowth, thus causing the stability of increased annual discharge.

The 1972 annual water yield increase of 3.76 area-inches (8.3 inches on an area-cut basis) represents the combined effects of both clearcuttings. A larger increase would have been expected had not saturated conditions existed on both watersheds due to tropical storm Agnes.

*Seasonal water yield.*—For analyzing the treatment effect on seasonal water yields, 1 May through 31 October was selected as the growing season and 1 November through 30 April as the dormant season. Seasonal prediction equations were derived by multiple regression, using runoff from the control watershed and average precipitation on the watersheds as the independent variables.

The effect of clearcutting on the growing-season water yields for 1967 through 1972 is shown in table 4. Significant increases were measured during each growing season of the phase-one after-treatment period. These increases ranged from 0.88 to 2.16 area-inches (4.4 to 10.7 inches on an area-cut basis) and were a direct result of decreased evapotranspiration and canopy interception. However, the distribution and amount of rainfall appeared to exert a strong influence on the magnitude of these increases. With the exception of 1968, the growing seasons with above-normal rainfall are also the growing seasons with the greatest response to treatment. When precipitation was near normal, as was the 1969 growing season, a considerably smaller increase occurred. The smallest increase in water yield, 0.88 area-inch, occurred during the 1968 growing season. Although precipitation during this period was 2.6 inches above normal, virtually all this increase fell during May and consequently had little effect on the overall 1968 growing season water-yield increase.

The 1972 growing season water-yield increase reflects the combined effects of both the phase one and phase two clearcuttings. Although an increase of 1.5 area-inches (3.3 inches on an area-cut basis) was measured, it was found to be nonsignificant. Here the effects of tropical storm Agnes on the magnitude of the independent variables used in the prediction equation become apparent. Precipitation during the 1972 growing season was 32.0 inches, 13 inches above normal. Streamflow from the treated watershed was 20.25 area-inches, 17 inches above the calibration period mean.

Since these values greatly exceeded any of the calibration data used in developing the prediction equation, the reliability of the statistical techniques used to determine the treatment effect and its significance became greatly reduced. Furthermore, water yield increases occur primarily during the growing season or recharge periods when a moisture-storage differential exists between the clearcut and forested areas. Because of the extreme rainfall during the 1972 growing season, saturated conditions existed on both treated and control watersheds, minimizing the effects of the timber harvest.

Treatment had a variable effect on the dormant-season water yields, as shown in table 4. Insignificant decreases in

stream discharge occurred in 1967 and 1968; increases were measured in 1969 through 1972. Of these, only the 1969 increase of 1.61 area-inches (8.0 inches on an area-cut basis) and the 1972 increase of 1.41 area-inches (3.1 inches on an area-cut basis) were significant. The 1972 increase represents the combined effect of both clearcutting treatments. These increases in water yield during the dormant season reflect the effects of treatment on soil moisture recharge and possibly on snow accumulation and melt. However, the magnitude of the treatment effect on the dormant-season discharge also reflects the amount of precipitation. Decreases in water yield in 1967 and 1968 were associated with below-normal precipitation. Conversely, the increase during the 1969 through 1972 dormant season were associated with above-normal precipitation.

*Monthly water yield.* — Regression equations developed from the calibration period were used to predict monthly water yield for watershed 2 for both after-treatment periods. Changes in streamflow as a result of phase one for May 1967 through November 1971 are presented in table 5. The combined effects of both clearcuttings for May 1972 through April 1973 are also shown in table 5. The magnitude of increased flow varied considerably. Significant increases after phase one ranged from a high in August 1967 of 0.64 area-inch to a low of 0.06 area-inch during July 1968. The range in significant increases for the combined effects of phase one and phase two is from 1.20 area-inches in June 1972 to 0.05 area-inch in September 1972. The exceptionally high increase in June 1972 is a direct result of tropical storm Agnes.

A rather consistent pattern in the timing of these increases in streamflow is evident for both after-treatment periods. In general, significant increases in water yield occurred primarily during the growing season months (May-October) and resulted from decreased evapotranspiration, increased soil moisture, and elimination of canopy interception. Significant increases in water yield during the dormant-season months resulted from the higher soil moisture content on the treated watershed as compared to the control watershed. Because of this, less precipitation is needed to recharge the soil reservoir on the treated watershed, leaving more available for streamflow. Increases in stream discharge that occur after the soil reservoir is recharged on both treated and control watersheds are due to the effect of treatment on snow accumulation and melt.

*Low flows.* — The number of days per year in which stream discharge was below 0.1 csm (100 gallons per acre per day) was used to determine the effect of treatment on low flows. Analyses of variance and regression analyses were used to determine the significance of change.

On the treated watershed, the number of days that flow was below 0.1 csm decreased from an average of 168 days per year during the calibration period to an average of 51 days per year during the six after-treatment years (table 6). At the same time, on the control watershed the number of days with flow below 0.1 csm decreased from an average of 175 days to 111 days. The effect of the above-normal precipitation during five of the six after-treatment growing seasons resulted in the decrease in the number of days with low flow on the control watershed and also accounted for part of the decrease on the treated watershed. Although analyses of variance indicated that no significant difference existed between the two watersheds before cutting it was not certain what effects of the treatments alone had on the significant reduction in the number of days with low flow. Therefore, regression analysis was used to determine the treatment

Table 5.—Effect of treatments on monthly streamflow from May 1967 through April 1973[1]

[All values are in area-inches]

| Month | 7-Year mean precipitation | 1967–1968 | | 1968–1969 | | 1969–1970 | | 1970–1971 | | 1971–1972 | | 1972–1973 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Y-\hat{Y}$[2] | Precipitation | $Y-\hat{Y}$ | Precipitation | $Y-\hat{Y}$ | Precipitation | $Y-\hat{Y}$ | Precipitation | $Y-\hat{Y}$ | Precipitation | $Y-\hat{Y}$ | Precipitation |
| May | 3.40 | +0.096 | 5.00 | +0.336* | 6.06 | +0.036 | 2.20 | +0.148 | 3.10 | +0.541* | 4.12 | +0.218* | 5.56 |
| June | 3.32 | +0.264* | 1.70 | +0.279* | 3.86 | +0.187* | 3.75 | +0.199* | 5.11 | +0.189* | 3.86 | +1.198* | 15.89 |
| July | 3.55 | +0.402* | 7.20 | +0.063 | 2.43 | +0.339* | 5.98 | +0.417* | 5.76 | +0.160* | 5.33 | +0.188* | 4.16 |
| Aug. | 3.49 | +0.639* | 4.85 | +0.039 | 2.22 | +0.274* | 3.63 | +0.272* | 4.50 | +0.136* | 1.52 | +0.094* | 1.23 |
| Sept. | 3.02 | +0.289* | 3.02 | +0.110* | 3.63 | +0.030 | 0.94 | +0.109* | 2.26 | +0.231* | 5.03 | +0.052* | 3.11 |
| Oct. | 2.23 | −0.101 | 3.86 | +0.206* | 3.44 | +0.065* | 2.36 | +0.631 | 3.62 | +0.230* | 2.36 | +0.138* | 2.05 |
| Nov. | 2.95 | −0.360 | 2.95 | +0.244* | 4.64 | +0.312* | 3.12 | −0.428 | 5.28 | +0.155* | 2.99 | +0.829* | 6.29 |
| Dec. | 2.10 | −0.205 | 3.01 | −0.229 | 2.86 | +0.195* | 4.05 | +0.105 | 3.75 | +0.048 | 3.72 | +0.118 | 4.96 |
| Jan. | 2.56 | −0.112 | 1.51 | −0.100 | 1.53 | +0.113 | 1.02 | +0.105 | 3.77 | +0.091 | 2.46 | −0.182 | 2.91 |
| Feb. | 2.85 | −0.028 | 0.72 | −0.093 | 0.69 | +0.366* | 3.55 | +0.307* | 4.85 | +0.262* | 3.43 | −0.049 | 3.26 |
| Mar. | 3.66 | −0.130 | 2.59 | −0.220 | 0.89 | +0.454* | 3.65 | +0.209 | 2.82 | −0.001 | 1.86 | −0.154 | 2.18 |
| Apr. | 3.55 | −0.019 | 1.31 | −0.055 | 2.74 | +0.195 | 4.90 | +0.029 | 0.71 | +0.175 | 4.82 | +0.062 | 4.59 |

[1]See table 4 for specific treatment periods.

[2]Actual streamflow–predicted streamflow.

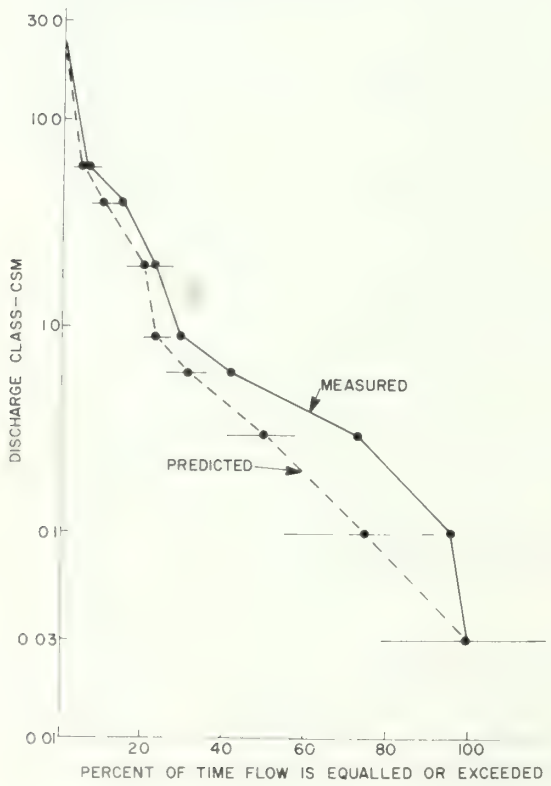
*Significant at 5 percent.

Table 6.—Comparison of the number of days per year that streamflow was below 0.1 csm

| Period | Control watershed | Treated watershed Y | Predicted No. of days $\hat{Y}$ | Difference $Y-\hat{Y}$ |
|---|---|---|---|---|
| Calibration period mean | 175 | 168 | — | — |
| After-treatment water year | | | | |
| 1967 | 87 | 56 | 16 | −40* |
| 1968 | 115 | 92 | 87 | −5 |
| 1969 | 158 | 146 | 84 | −62* |
| 1970 | 99 | 71 | 26 | −45* |
| 1971 | 115 | 92 | 53 | −39* |
| 1972 | 95 | 66 | 40 | −26* |
| After-treatment mean | 111 | 51 | 87 | −36* |

*Significant at 5 percent.

Figure 5.—Effect of partial forest removal on the growing-season flow-duration curve.




effect. The results indicate that treatment alone resulted in significant reductions in the number of days of low flow for five of the six after-treatment years. The significant reductions of low-flow days ranged from 26 in 1972 to 62 in 1969 and averaged 36 days over the after-treatment periods. The 1968 water year, the only year of below normal precipitation, had a nonsignificant decrease of 5 days.

*Flow duration.*—Flow-duration analyses based on mean daily flow in csm were used to show the treatment effect on various discharge classes. From the calibration data, prediction equations were computed for selected flow classes for the growing, dormant, and annual periods. These equations were then used to predict the average flow-duration curve for the treated watershed for each season during the after-treatment periods.

Average predicted and measured flow-duration curves for the clearcut watershed during the growing season are shown in figure 5. The measured flow-duration curve is above, or to the right of, the predicted curve for almost all flow classes and reflects the treatment

Figure 6.—Effect of partial forest removal on the dormant-season flow-duration curve.

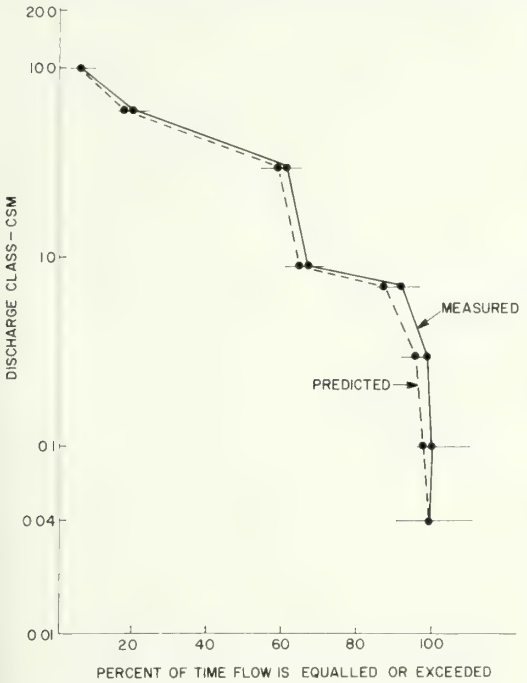
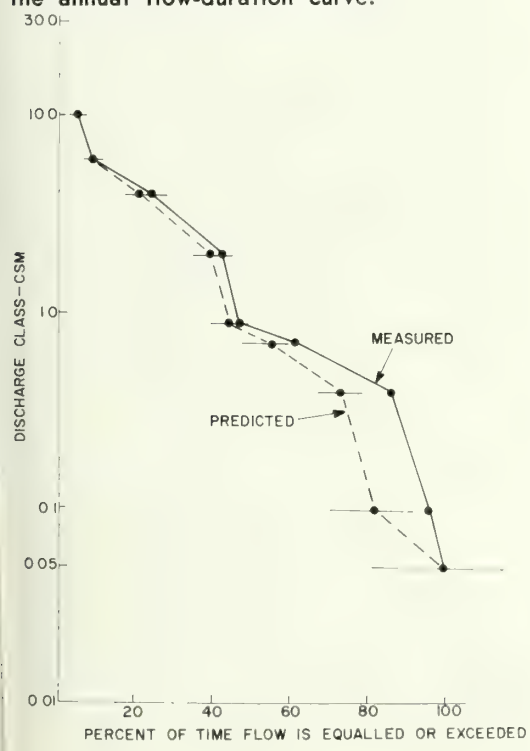



Figure 7.—Effect of partial forest removal on the annual flow-duration curve.




effect. Since the measured curve lies outside the 5-percent confidence interval for each flow class of the predicted curve, the treatment effect is significant. In general, there has been considerable augmentation of the low and median flows (below 0.4 csm) and relatively smaller increases in high flows (above 1.0 csm).

The effect of treatment on discharge during the dormant season is shown in figure 6. Again, the average measured flow-duration curve is above the predicted curve for almost all flow classes. However, the measured curve, for the most part, falls within the confidence intervals about the predicted curve, thus indicating a nonsignificant treatment effect for most flow classes. A significant change was detected for only the 0.1 to 0.3 csm flow class.

Predicted and measured average annual flow-duration curves are shown in figure 7. A comparison of these curves shows an increase in the measured curve for almost all flow classes, the most pronounced change occurring in the median- and low-flow classes. The number of days with flow exceeding 0.7 csm was not significantly changed.

*Runoff as a percent of precipitation.*—The effects of clearcutting on runoff as a percent of precipitation for both the growing season and annual water years during both after-treatment periods are shown in table 7. Using regression analysis to determine treatment effect, we observed significant increases in runoff as a percent of precipitation for 1967 through 1971 for both the growing season and annual water years. Significant increases during the growing season ranged from 4.6 percent in 1968 to 9.5 percent in 1967. On an annual basis, significant increases ranged from 4.0 percent in 1968 to 7.8 percent in 1970. In all cases, significant increases in runoff as a percent of precipitation corresponded to significant increases in

Table 7.—Effect of treatments on runoff as a percent of precipitation

| Period | Predicted | Actual | Difference |
|---|---|---|---|
| | GROWING SEASON | | |
| 1967 | 24.9 | 34.4 | 9.5* |
| 1968 | 20.3 | 24.9 | 4.6* |
| 1969 | 8.5 | 13.8 | 5.3* |
| 1970 | 9.7 | 17.6 | 7.9* |
| 1971 | 14.0 | 21.8 | 7.8* |
| 1972 | 58.7 | 63.6 | 4.9 |
| | ANNUAL | | |
| 1967 | 43.4 | 49.5 | 1.6* |
| 1968 | 32.7 | 36.7 | 4.0* |
| 1969 | 38.5 | 46.1 | 7.6* |
| 1970 | 46.2 | 54.0 | 7.8* |
| 1971 | 46.1 | 52.3 | 6.2* |
| 1972 | 63.8 | 69.3 | 5.5 |

*Significant at 5 percent.

stream discharge. Although a relatively large increase in runoff as a percent of precipitation occurred during the 1972 growing season and annual water year, they were nonsignificant.

Again, the effect of tropical storm Agnes on the 1972 growing season and annual precipitation and runoff drastically affected the reliability of the statistical techniques used to determine treatment effect and its significance. During the extremely wet conditions of 1972, growing-season runoff as a percent of precipitation increased from a 16 percent average during the calibration period to 64 percent. Approximately 70 percent of this increase resulted from tropical storm Agnes. The annual runoff as a percent of precipitation increased from an average of 35 percent during the calibration period to 70 percent during 1972, tropical storm Agnes accounting for 57 percent of this increase.

*Storm hydrograph.* — The effects of the lower-slope treatment on storm hydrograph parameters also were studied. The parameters selected were quickflow volume, instantaneous maximum peak, antecedent flow rate, time to peak, and time of recession. A total of 46 events was selected from the calibration period and 37 from the after-treatment period (April 1967-August 1970). The hydrographs selected were from single storm events that produced a quickflow volume of 0.01 area-inch or more and occurred during non-snowmelt periods. These events were then classified according to whether they occurred in the growing or dormant season. A downward stepwise multiple-regression technique, using maximum rainfall intensity, duration of rainfall before the maximum peak, duration of rainfall after the maximum peak, and total precipitation as the independent variables, was used to develop prediction equations for each of the hydrograph parameters. These prediction equations were then used to detect any change in the selected hydrograph parameters due to treatment.

The results (table 8) indicate that treatment affected the storm hydrograph by significantly increasing quickflow volume, instantaneous maximum peak, antecedent flow rate, and time of recession, while decreasing the time to peak. In general, these increases were most evident during the growing season.

Although the removal of the forest cover did significantly increase the volumes of stormflows and instantaneous peakflows, the large increases occurred primarily in storms during the growing season at relatively low antecedent flow conditions and therefore do not represent any potential increase in flood threat.

The effects of both treatments on five storm hydrographs, excluding tropical storm Agnes, were similar to those encountered after the lower-slope clearcutting. The time to peak decreased for all five storms, while the antecedent flow rate and time of recession increased. The instantaneous maximum peaks and quickflow volumes showed variable re-

Table 8.—Effect of lower-slope treatment on storm-hydrograph parameters

| Storm-hydrograph parameter | Growing season | After-treatment period[1] |
|---|---|---|
| Quickflow volume | +171% (0.07 inch)* | + 32% (0.02 inch)* |
| Instantaneous maximum peak | +351% (25.6 csm)* | +118% (10.5 csm)* |
| Antecedent flow rate | +123% (0.20 csm)* | + 12% (0.10 csm)* |
| Time to peak | − 3% (0.11 hrs.) | − 3% (0.11 hrs.) |
| Time to recession | + 33% (4.2 hrs.)* | No change |

[1]April 1967 through August 1970.
*Significant at 1 percent.

Table 9.—Comparison of the average storm-hydrograph parameter during the calibration period with tropical storm Agnes

| Storm-hydrograph parameter | Control | | Treated | |
|---|---|---|---|---|
| | Calibration period average | Tropical storm Agnes | Calibration period average | Tropical storm Agnes |
| Quickflow volume (inches) | 0.075 | 9.16 | 0.076 | 9.75 |
| Instantaneous maximum peak (csm) | 9.4 | 177.0 | 10.7 | 190.0 |
| Time to peak (hours) | 5.7 | 49.0 | 5.2 | 40.0 |
| Time of recession (hours) | 16.1 | 111.2 | 16.0 | 114.5 |

sponse. Increases were observed for some storms, while for others, decreases were measured. Although the middle-slope clearcutting significantly altered some of the storm-hydrograph parameters for some storms, the overall effects of both treatments were not significantly different from those resulting from the lower-slope treatment.

For tropical storm Agnes, the effects of treatment on the storm-hydrograph parameters did not follow the general trends in all instances. Quickflow volume, instantaneous maximum peak, and time of recession show large negative differences between the actual and predicted values rather than positive differences. Deviations from the trends shown by the other storms can be attributed to the magnitude of Agnes when compared with the relatively small storms on which the prediction equations were based (table 9). Total runoff from Agnes on the treated watershed amounted to 10.94 area-inches. This represents 92.8 percent of the 11.79 inches of rain that fell during Agnes. On the control watershed, total runoff amounted to 10.09 area-inches or 85.5 percent of the total rainfall. The quickflow volumes (table 9) accounted for 91 percent on the total runoff on the control watershed and 89 percent on the treated watershed.

## CONCLUSIONS

The two-phase clearcutting of approximately 48 acres of Leading Ridge Watershed 2 (106 acres) produced the following effects on water quantity and quality:

1. During the lower-slope logging period, maximum storm turbidity was 550 ppm on the treated watershed;

the control watershed never exceeded 25 ppm. Most turbidity, which could be traced to scarified log-loading areas, decreased immediately after completion of logging. Increased water turbidity as a result of cutting the middle-slope portion of the watershed was negligible. Maximum storm and nonstorm water turbidity on both watersheds never exceeded 13 ppm. In general, restrictive logging practices prevented any serious stream sedimentation.

2. Maximum water temperatures increased an average of 7°F (61 to 68°F) during the summer months (June through August) as a result of the lower-slope clearcutting and 8°F (66 to 74°F) after completion of both treatments. Minimum water temperature showed little change as a result of either clearcutting.
3. The combined lower- and middle-slope clearcuttings had little, if any, apparent effect on the average concentration of calcium, magnesium, potassium, sodium, sulfate, and nitrate.
4. Clearcutting had no effect on stream water acidity expressed as pH.
5. Water-yield increases resulting from clearcutting occurred primarily during the growing season and ranged from 0.88 to 2.16 area-inches (4.4 to 10.7 inches on area-cut bases) after completion of the lower-slope logging.
6. Dormant-season flows showed a variable effect. Only the 1969 increase of 1.61 area-inches and the 1972 increase of 1.41 area-inches were significant. These increases are equivalent to 8.0 and 3.1 inches on an area-cut bases.
7. Annual water-yield increases ranged from 1.22 to 2.87 area-inches (6.1 to 14.0 inches on an area-cut bases) after the lower-slope clearcutting. The combined treatments resulted in an annual water-yield increase of 3.76 area-inches (8.3 inches on an area-cut bases).
8. Both the lower-slope and middle-slope treatments had major effect on low flows. The number of days per year of flow under 0.1 csm on the treated watershed decreased from an average of 168 to 51 during the after-treatment periods.
9. The lower-slope treatment affected the growing-season storm hydrographs by significantly increasing quickflow volumes, instantaneous maximum peaks, and time of recession, while decreasing the time to peak. Storm antecedent flow rates were also increased. The middle-slope clearcutting significantly altered some storm-hydrograph parameters for some storms; however, the overall average effects of both treatments were not significantly different from those following the lower-slope treatment.


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# EFFECTS OF MANAGEMENT PRACTICES ON WATER QUALITY AND QUANTITY: THE NEWARK, NEW JERSEY, MUNICIPAL WATERSHEDS

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*ABSTRACT.* The 36,000-acre Pequannock Watershed, owned by the City of Newark, New Jersey, provides about one-half of the water supply of Newark and adjacent cities. The collection and delivery of high-quality water to the city is the primary management objective. The Newark Division of Water Supply and the Northeastern Forest Experiment Station in 1959 initiated a cooperative study of the effects of chemical control of vegetation on water quality and yield. Three forested watersheds (oak-hickory type) in the Pequannock drainage, ranging from 24 to 68 acres, were used. Riparian zone vegetation was deadened on one watershed with herbicides (using tree injection and mistblower application) to stimulate a streamside treatment that has been practiced on the Pequannock in the past. Herbicides were used to deaden overstory vegetation on another watershed. The effects of gypsy moth defoliation on water yield are quantified. The use of vegetation treatments in the management of a municipal watershed is discussed.

A WATERSHED MANAGER is interested in water production and quality as related to forest conditions, in addition to all the other problems of tree growth, disease and insect damage, planting, fire protection, property locations, timber sales, recreation pressures, etc. This interest may vary from year to year depending on the amounts of precipitation and the level of water in storage reservoirs during the summer and early fall when streamflow is lowest.

Newark's 36,000-acre Pequannock watershed provides about one-half of the water supply for the city and surrounding communities. It is almost entirely forested. The main objective of the management program on the Pequannock watershed is to collect and deliver high-quality water for domestic and industrial use. Many of the city's industries are geared to a plentiful supply of clean, soft water and could be affected by a

decrease in either quantity or quality of supply. In recent years the watershed is also being looked to for recreation and education, for new revenue-producing uses that may aid in decreasing the property tax burden of the city, and for open space that future generations may enjoy.

To obtain a quantitative evaluation of how the forest-water yield relationship may be affected by control of vegetation on municipal watersheds, the Northeastern Forest Experiment Station and the City of Newark, New Jersey, Division of Water Supply, initiated the study described in this paper.

## EXPERIMENTAL WATERSHEDS

Three adjacent watersheds within the Pequannock basin were selected for the study. The watersheds have a southeast aspect and lie between 900 and 1,200 feet in elevation. Slopes are gentle near the stream-gaging stations but steeper near the ridge of Copperas Mountain. Watersheds 2 and 3 are 42 and 23 acres in area, respectively. Watershed 1 is 68 acres, and its stream-gaging station is at the end of a long flat stretch of bouldery stream channel. All watersheds had intermittent summer flow during the drought period years 1962-65.

Forests of the oak-hickory type completely covered all three watersheds. Soils range from very poorly drained and swampy to well drained and very stony to bouldery. Soils are usually less than 24 inches deep, and much of the surface is covered with stones or boulders, especially on the upper portions of the watersheds. Rock outcrops are common. Mid-slope soils are deeper and are moderately well to poorly drained. Site quality is generally low. Repeated cuttings for charcoal and a series of wildfires have reduced the forest quality to a level probably lower than the site would normally support.

## HYDROLOGIC EFFECTS OF DEADENING FOREST VEGETATION ON AN ENTIRE WATERSHED

### *Application of Herbicides by Injection*

Partly because of their substantial transpiring surfaces and extensive root systems, trees use a lot of water compared to other forms of vegetation. Experiments in several parts of the East have shown that harvesting trees on a watershed can save a considerable amount of water *(Lull and Reinhart 1967)*. Because there was no market for the low-grade timber on the experimental watershed, we decided to deaden the trees with herbicides, simulating a clearcutting, to find out if water yield could be increased.

On watershed 3, all trees larger than 1 inch in diameter (approximate diameter at ground surface) were injected with a herbicide (either Tordon or Weedone) in the fall of 1965. In addition, Weedone was applied by mistblower on several areas of dense undergrowth. By the summer of 1966, live overstory vegetation had been reduced to 31 percent of the watershed area. Live trees less than 1 inch in diameter were present on 10 percent of the area. In general, a good tree kill was achieved on the drier sites in the upper portion of the watershed. The kill varied from moderate to poor on the deeper soils where moisture conditions were more favorable. The incomplete kill was due in part to missed stems, especially in areas containing many small ones. Grasses and herbs increased in response to the reduction in overhead shading and in 1966 covered 26 percent of the watershed.

### *Application of Herbicide by Aerial Application*

To complete the deadening of forest vegetation on watershed 3, an aerial application of herbicide was made by helicopter in June 1967. The 2,4,5-T

(low volatile ester) was applied at the rate of 4 pounds acid equivalent mixed with 3 gallons of water and 1 gallon of fuel oil per acre. Watershed boundaries were marked with fluorescent bags filled with brush and tied to the tops of trees. Criteria were established to permit spraying only when wind speed was less than 3 mph, to minimize drift. The job was conducted in the early morning, and wind speeds never exceeded 1 mph.

To check on possible contamination of streamflow by the herbicide, water samples were collected. Control samples were taken at the stream-gaging stations at watershed 2 (the control watershed) and watershed 3 before the spraying operation. Other samples were taken at the same stations during and at the conclusion of the spraying operation and at 1, 2, 4, 8, 24, and 48 hours afterwards. Samples were also taken 1 mile downstream from the experimental watersheds. Additional samples were collected after rainstorms into July. Samples were refrigerated until analyzed by an independent laboratory, using gas chromatography with electron capture techniques.

By late summer, live overstory vegetation had been reduced to 3 percent of the 1965 stocking. Ground cover continued to increase and covered 41 percent of the watershed. There was no evidence of vegetation damage outside the boundaries of the experimental watershed.

Only one water sample, taken in an open channel area just after a helicopter pass, showed a trace of herbicide. All other samples were negative.

### *Effects of Treatments on Water Yield*

Treatment effects were based on changes in streamflow during the May 1 — April 30 water-year. Growing season (May-October) and dormant season (November-April) evaluations were also made.

Table 1.—Increases in annual water yield from deadening vegetation on watershed 3

| May 1 water-year | Increase[1] | Equivalent increase |
|---|---|---|
| | *Inches* | *Gallons/acre* |
| INJECTION OF HERBICIDES FALL 1965 | | |
| 1966–67 | 4.67 | 126,809 |
| AERIAL APPLICATION OF HERBICIDES JUNE 1967 | | |
| 1967–68 | 7.79 | 211,530 |
| 1968–69 | 5.06 | 137,399 |
| 1969–70 | 5.52 | 149,890 |
| 1970–71 | 3.53 | 95,854 |

[1]Significant at 1-percent level.

Reduction in vegetation cover following the injection of herbicides resulted in a water-yield increase of 4.67 inches (table 1). This is an increase in water production of 127,000 gallons of water per acre per year.

A larger increase in water yield was obtained after the aerial application of herbicide. An annual increase of 7.79 inches was measured, which amounts to about 212,000 gallons of water per acre (table 1). This additional water totaled 5 million gallons from the 24-acre watershed. Most of this increase was yielded during the growing season.

In summer 1968, ground cover had increased to 90 percent while overstory vegetation covered 4 percent of the watershed (fig. 1). Fifty-seven percent of the ground cover consisted primarily of the tall densely-growing white fireweed *(Erechtites hieracifolia)*.

In contrast, ground cover was virtually absent in the forested control watershed (fig. 2). Some hardwood sprouts and new seedlings developed in the treated watershed. About 1,500 Scotch and Austrian pine seedlings were planted. The watershed still had

Figure 1.—Watershed 3 had a heavy cover of grasses and herbs a year after the aerial application of 2, 4, 5-T. Live trees in the right center of photograph are on the control watershed.





Figure 2.—Ground cover is virtually absent in the forested control watershed.

a continuous cover of litter 2 to 3 inches thick. No areas of bare soil or surface erosion were discernible. Firewood cutters were allowed to remove the dead trees to reduce the fire hazard and improve the safety and appearance of the area.

The increased water production began to decline in response to vegetation regrowth (table 1). Four years after the aerial application, the water-yield increase had been reduced by 55 percent. According to methods of Lull and Reinhart *(1967)* and Douglass and Swank *(1972)* there would be a water-yield increase for 12 years. However, the increase would be less than 1 inch after the 8th year.

The rate of decline is not always accurately defined because of precipitation variations in the after-treatment years. For instance, the 15 inches of rainfall in May-June 1968, 2.3 times normal, minimized the effects of the vegetation treatment during the early growing season. This influence is shown in the 1968-69 water-year (table 1).

### Effects of Treatment on Other Hydrologic Parameters

*Low-flow days.*—The number of days per year in which stream discharge was below 0.1 csm (cubic feet per second per square mile), or approximately 100 gallons per acre per day, was used to determine the effects of treatment on low flows. The herbicide treatment resulted in considerable augmentation of low flows. During the 5 years after the first treatment, the number of low-flow days was reduced from an average of 81 days per year to an average of 35 days per year.

*Streamflow timing.* — Streamflow timing (concentration) can be characterized by the shortest number of consecutive days that accounts for high flows and the longest number of consecutive days that accounts for low flows *(Sopper and Lull 1970)*. The half-flow interval for high flows is defined as the shortest winter-spring period that includes one-half of the annual flow. The 5-percent flow interval for low flows is defined as the longest period that accounts for 5 percent of the annual flow.

The shorter the time period in which half the annual flow runs off, the greater the concentration of flow and possibility of wide variation in annual streamflow. Where half-flow intervals are longer, flow is discharged over a longer period of time, and the annual regimen shows less variation. The shorter the low-flow interval, the less spread out the low flow, with consequently less variation in the annual regimen.

After treatment, the half-flow interval increased by an average of 26 days per year for the five after-treatment years. The 5-percent flow interval was reduced by 33 days per year for the same period. This influence was most pronounced during years of low precipitation. Both results confirm that the treatment tended to provide a more uniform flow of water into the reservoir system by sustaining streamflow during the low-flow period of summer and fall.

*Peak flows.* — A peak-flow analysis was made for all storm events that produced flows exceeding 10 csm on the control watershed. Instantaneous peak flows on watershed 3 were increased by 17.3 percent (8.2 csm) during the growing season as a result of the vegetation treatment. These increases occurred during periods when soil moisture was higher on the treated watershed due to the reduction in interception and transpiration losses. Because relatively low flows prevail during this summer period, increases are much below flood magnitude. Effects on peak flows during the dormant season were minor or nonexistent, because little or no difference in moisture storage existed between the forested and deforested watersheds.

*Stream temperature.* — Stream water temperature increased during the growing season as a result of removing overstory vegetation. Average summer (June, July, and August) maximum water temperature increased 6°F (68° to 74°F) compared to the control watershed during the first 3 years after treatment. Mean water temperature increased 4°F (62° to 66°F) during the same period. Minimum water temperatures during the summer months were generally unchanged, as were temperatures during the dormant season. Temperatures approached pretreatment normals by the fourth and fifth year after treatment as vegetation began to shade the stream channel again.

*Turbidity.* — Stream turbidity was measured once a week at the time of chart changing. Stream turbidity after the herbicide treatment was 1.6 ppm for the control watershed and 1.8 ppm for the treated watershed. Maximum turbidities measured were 7.5 ppm on the control watershed and 6.5 ppm on the treated watershed. Highest flow sampled on the treated watershed was 26.2 csm.

## EFFECTS OF GYPSY MOTH DEFOLIATION ON WATER YIELD

### *The Situation*

A severe gypsy moth outbreak occurred in the spring of 1971 on the Pequannock Watershed. Defoliation on the forested portions of the experimental watersheds was extensive. The timing of the outbreak provided an opportunity to evaluate one of nature's defoliation techniques on water yield.

Five growing seasons after the first



Figure 3.—Gypsy moth defoliation under way on watershed 2 in the spring of 1971. Area in right foreground is watershed 3.

erbicide treatment, watershed 3 still ad a relatively small percentage of its rea in overstory vegetation. Consequently there was little defoliation damge. However, trees on the control vatershed (No. 2) were severely deoliated (fig. 3). By the end of June and arly July, trees in the top half of the vatershed were completely defoliated, vhile trees on the rest of the watershed vere partially defoliated. By July, approximately 75 percent of the overstory eaves had been destroyed. The trees ut forth a second crop of leaves at the nd of the summer following heavy ains in late August.

### lethods Used to Determine hange in Water Yield

Two methods were used to estimate ne effects of gypsy moth damage on vater yield. In one method the herbiided watershed was used as a control, nd an equation was developed to preict streamflow of watershed 2 from treamflow measured at watershed 3. 'he calibration period was the 5 years uring which vegetation on watershed 3 vas deadened and watershed 2 was forsted. Admittedly, vegetation on Waterhed 3 was in a state of flux during this eriod. However, we felt the calibration vould be sensitive enough to detect a arge change in streamflow, if one ocurred, as a result of the defoliation.

In addition to the control-watershed pproach, we tried to obtain another ndependent estimate of the defoliation ffects on water yield. An estimate ased on calibrating a single watershed vas used. Regression equations were leveloped to predict streamflow of vatershed 2 from precipitation paramters. Twelve years of data were availble for this calibration. A correlation oefficient of 0.978 was obtained for the nnual water-yield equation.

### Water-Yield Increases Following Gypsy Moth Defoliation

The gypsy moth defoliation had a substantial influence on water yield. Annual water yield was increased by 5.82 inches as estimated by the control-watershed technique, while the single-watershed calibration method estimated the increase at 4.89 inches. Both values were statistically significant at the 5-percent level. Eighty percent of the yield increase came during the growing season. If we accept an average of the two estimates, 5.36 inches, as our quantitative estimate, water production was increased by 146,000 gallons per acre.

## CONTROL OF STREAMSIDE VEGETATION: EFFECTS ON WATER YIELD

### Vegetation Treatments

On watershed 1 all trees 1 inch in diameter (approximate diameter at ground surface) and larger within a zone 20 feet on each side of the stream channel were injected with ANSAR 160 herbicide in May 1965. The remaining live vegetation was sprayed with Weedone herbicide applied by a portable mistblower. Sopper *et al. (1966)* have shown that phenoxy herbicides can be used to control riparian vegetation on municipal watersheds, if properly applied, without constituting a water-pollution hazard.

This treatment was designed to simulate the program in streamside vegetation control that has been in operation for many years on the Pequannock Watershed. Vegetation has been cut and removed, or deadened by herbicide, within a strip 20 feet wide on each side of the feeder streams. The purpose of the program is to remove vegetation (1) that dropped its leaves into the stream, causing color and chemical build-up in the raw water, and (2) to prevent debris build-up that might cause stream blockage. Reducing the amount of vegetation in this zone of moist soil



Figure 4.—A heavy grass cover was already established when trees in the treated zone were cut.

might also affect water yield by lowering transpiration losses.

The chemical treatments were not completely effective. As of mid-June about one-half of the normal transpiring surface still remained. Red maple and yellow birch were the least damaged. Generally the amount of damage was related inversely to the diameter of the trees. The amount of live vegetation in the treated zone was lower in 1966 following some retreatment. In the winter and early spring of 1967, all trees in the treated zone were felled. A vigorous ground cover and some tree reproduction had developed in the cleared area by this time (fig. 4).

At the end of the 1967 growing season, the treatment zone was widened. Herbicide injection was used to treat all trees in an area up to 5 feet in elevation above the stream channel. This widened the treatment area to approximately 40 feet on each side of the channel. The treatment was 50 percent effective. After the 1968 growing season, all trees in the expanded treatment zone were felled and the slash was burned.

#### *Analysis of Treatment Effects*

There were slight but statistically nonsignificant growing-season streamflow increases following treatment. The increases averaged 0.12 inch for the three after-treatment years. The nonsignificant increases in streamflow may be due to the small area treated, 1.2 per cent of the watershed area, or to the incomplete vegetation kill. In addition, it is suspected that some of the strean

channel is above the groundwater table, and that deep seepage may be discharged downstream from the stream-gaging station, reducing the sensitivity of this experiment.

There was a definite reduction in diurnal fluctuation of streamflow during the 1967 growing season, indicating that transpiration losses had been reduced. This reduction had been slight in 1965 and 1966 following the herbicide treatment.

The effect on water yield of widening the treatment zone was also difficult to determine. Growing-season streamflow for 1968 through 1970 averaged 0.23 inch above predicted values. The increases in streamflow would represent approximately 9.5 inches additional water per acre treated for both the 40-foot and 80-foot treatment zones. However, changes in streamflow, as determined on a growing-season or an annual water-year basis, were not statistically significant. There was a substantial reduction in diurnal fluctuation during the 1968-70 growing seasons. This reduction disappeared after 1970 as a dense crop of aspen and birch developed in the treatment zone.

There was a slight increase in mean maximum stream temperature during the growing seasons on the order of 3°F. Stream turbidity was not increased as a result of the treatments. All felling of trees had been done during the winter months on snow or frozen soil. A low channel gradient and development of an early grass cover after the first herbicide treatment were important factors in preventing erosion. Average turbidity during the treatment periods averaged 1.6 ppm for both control and treated watershed. Maximum turbidity measured on watershed 1 was 7.9 ppm.

## DISCUSSION

Information gathered during this study showed that water production can be substantially increased by deadening vegetation on a watershed. The increased water is yielded primarily during the summer and early fall months.

The limited riparian vegetation treatment was not effective in producing statistically significant increases in water yield. There was a definite reduction in transpiration losses by streamside vegetation and indications that increases in water yield occurred during the growing season.

Gypsy moth defoliation caused a substantial increase in streamflow. However, we do not recommend it as a water-yield improvement method. Resulting tree mortality in 1971 was estimated at 16.5 million board feet on the Pequannock Watershed *(Newark Division of Water Supply 1971)*.

One might ask if vegetation treatments, either timber-harvesting or chemical vegetation control, are really needed or are practical for increasing water production in the Northeast? Look at one case history.

1965 was the fifth consecutive year of below-average precipitation on the Pequannock Watershed. Precipitation totaled 32.50 inches, 16.51 inches less than the 73-year average of 49.01 inches. At the start of 1965, Pequannock water storage was 2.8 billion gallons or 19.5 percent of the total storage capacity. This was 840 million gallons less than storage at the start of the previous year. Loss in storage continued until February 3, 1965, when it reached 2.05 billion gallons (14.3 percent of total storage), the lowest storage on record up to that date. Gains in storage were very gradual and reached a maximum of 4.83 billion gallons (33.5 percent of storage) on May 11, 1965. Depletion then started. Emergency measures

slowed the rate of drawdown, in spite of which storage dropped to 1.08 billion gallons (7.6 percent of total storage capacity) on December 13, 1965. This is less than one-third of the 25 percent reserve, which is not considered a part of the storage in figuring safe yield of the water supply *(Newark Division of Water Supply 1965)*. At 1966 delivery rates, this represented a 20-day water supply, a portion of which was not obtainable without pumping. At 1970 delivery rates, the supply would have lasted for 16½ days.

A slight gain occurred by the end of the year to 1.48 billion gallons (10.3 percent of storage capacity). Threat of complete depletion was averted only by the narrowest of margins. Thirty percent less water was sent to the city in 1965 than in 1964. One and a half billion gallons of otherwise unavailable water was pumped into the Pequannock system from Lake Wawayanda, Echo Lake, and Hanks Pond *(Newark Division of Water Supply 1965)*.

Such situations are especially critical for communities with small water-storage capacities. In such cases there is little carryover from years of plentiful supply to years of shortages.

From 1945 to 1972, 34 percent of the water yield from the Pequannock Watershed was lost through overflows in the reservoir system. In many of those years this water was not needed. However, overflows for the two years preceding the 1962-66 drought were 44 percent and 49 percent respectively of the total water yield. Creation of additional storage capacity may be one answer. But this can be expensive, and in many parts of the Northeast the best reservoir sites are already in use.

During extended drought periods, additional storage capacity may not be entirely sufficient unless this capacity is large. Under such conditions a program of vegetation management to augment low water yields in the summer and fall would be extremely beneficial.

For example, an even-aged sustained-yield management program on the Pequannock Watershed, such as harvesting timber on 500 acres per year in small blocks, could substantially increase water yield. Twelve years into such a program, and as long as the program was maintained, an increased average annual water yield of 440 million gallons could be expected and would come primarily in the summer and fall months. Partial cutting under all-aged management would have a much smaller and shorter-lived effect on water yield. Additional benefits would include deriving municipal income from the timber sales and improvement in the growing stock. Other management programs to augment water yield by periodically harvesting timber on portions of a municipal watershed have been described by Lull and Reinhart *(1967)*.

Before any program of vegetation management is put into effect, there are several values to consider in addition to water supply. How will the proposed vegetation treatments affect aesthetic values? Many municipal watersheds in megalopolis are major open-space areas and provide visual relief from a man-created urban-industrial landscape. The creation of vistas within the watershed property is also an important consideration.

How will the proposed vegetation treatments affect recreation values? Pressures are mounting for increased use of municipal watersheds for recreation. Recreation areas may have to be managed differently than other parts of the watershed. What are the possibilities for wildlife enhancement? A dirt road through watershed 3 has been frequently used by hikers because they can see for a distance and observe wildlife, vegetation changes taking place, and plants and songbirds of openings (ones

not found in mature forests). Increases in stream temperatures due to removal of forest vegetation will have to be evaluated in terms of their effects on the aquatic habitat. Use of buffer strips to shade the stream might be considered.

How will the proposed vegetation treatments affect timber values? Many forestry practices can benefit both timber and water production. While merchantable timber could be salvaged before or just after deadening by herbicide, the future value of the growing stock would be entirely lost.

Perhaps we need to work out procedures to brown-out a canopy without killing the trees in years of water shortages. Even better would be the development of effective anti-transpirants and methods for their application to reduce the use of water without damaging vegetation. This would be especially helpful near recreation areas and where aesthetic considerations are important.

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# EFFECTS OF MANAGEMENT PRACTICES ON WATER QUALITY AND QUANTITY: HUBBARD BROOK EXPERIMENTAL FOREST, NEW HAMPSHIRE

*by* JAMES W. HORNBECK *and* C. ANTHONY FEDERER, *respectively Forest Hydrologist and Forest Meteorologist, USDA Forest Service, Northeastern Experiment Station, Forestry Sciences Laboratory, Durham, New Hampshire.*

*ABSTRACT.* A hypothetical dialogue between forest hydrologists and a municipal watershed manager illustrates the knowledge gained from research at Hubbard Brook. When forest vegetation is cut, water yield increases, especially when it is most needed during critical low-flow periods in late summer and early autumn. Unless measures are taken to control regrowth, the water yield returns to pre-treatment levels within several years. The normally high quality of streams from northern hardwoods can be lowered by any reduction in vegetative cover sufficient to materially increase water yield. Nutrient leaching is accelerated after cutting and dissolved solid content of streams is subsequently increased. Erosion, sediment, and increased water temperature are also problems associated with cutting; however, they can be minimized by taking known precautions.

WE HAVE CHOSEN to present research results from the Hubbard Brook Experimental Forest in the form of a dialogue. Our intent is to illustrate kinds of information available for assisting watershed managers in decision-making. Participants in our hypothetical dialogue are forest hydrologists (FH) involved in the Hubbard Brook experiments and a municipal watershed manager (MWM) for a community in upland New England.

*MWM.* The town I work for gets most of its water from a forested upland watershed several square miles in area. It's covered with old-growth northern hardwoods interspersed with patches of conifers. Climatological data from the nearest weather station show that precipitation is evenly distributed throughout the year and averages about 40 inches. Snow cover is usually continuous from December through March and gets to be about 2 or 3 feet deep. The soil seems to be coarse-textured and shallow.

Our water supply is drawn from a small dam in the stream channel near the base of the watershed. Late-summer flow is usually too low to satisfy our

demands, and we must augment from alternate, more expensive, and lower quality sources. So my first question is: What information is available on how we might increase water yield, particularly in late summer?

*FH.* We might first point out that low summer flow is characteristic of streams and uncontrolled rivers throughout the Northeast. Although precipitation is evenly distributed throughout the year, less than 10 percent of annual streamflow occurs from June through September. Small streams often dry up; but in larger river valleys, flow is maintained by groundwater stored in the valley alluvium. The reason is that nearly all the precipitation falling on forests during this period is returned directly to the atmosphere by evaporation and transpiration (termed evapotranspiration or ET). The water never has a chance to reach the stream. Of that 40 inches of annual precipitation of yours, only about half of it becomes streamflow. The other half becomes ET. And in summer nearly all the rainfall becomes ET. So the key to increasing summer yield is to decrease ET.

In the forest, ET dries the soil, producing what we call a soil-water deficit. When rain falls, it first rewets the soil. Only after the soil is fully recharged — that is, the soil-water deficit is eliminated — can additional rain move through the soil and become streamflow. In northeastern summers such full recharge seldom occurs if the summer rainfall is normal or below normal. However, when trees are cut or killed, ET is reduced and soil-water deficits are smaller. A smaller amount of rainfall is then required to recharge the soil, and a larger amount finds its way to the stream.

Figure 1.—Strip-cutting and complete forest clearing experiments in progress on gaged watersheds at Hubbard Brook.



*MWM.* So cutting the forest reduces ET and increases streamflow in summer. How much of an increase could I get by cutting?

*FH.* We have treated two watersheds at Hubbard Brook to study possible increases in water yield (fig. 1). The first treatment began in late 1965 and involved complete forest clearing by cutting all woody vegetation and leaving it where it fell. Herbicides were then applied for three successive summers to minimize regrowth of vegetation. For each of the 3 years in which herbicides were used, water yield increased an average 11.4 inches, nearly 300,000 gallons per treated acre. Nearly all of the increase came in late summer and early autumn.

A second watershed treatment that involves progressive strip-cutting was started in autumn 1970. One-third of the watershed is being harvested every other year by cutting a series of 80-foot-wide strips. This practice is a recommended form of management for regenerating a forest that will have a high proportion of valuable birch species. For the 2 years after cutting the first set of strips (one-third of the watershed area cut over), streamflow from the watershed increased by an average of 1.3 inches per year, or 35,000 gallons per watershed acre. Most of the increase was found to occur in late summer.

*MWM.* So complete clearing will give me 11 inches more water over the cleared area at the time I need it the most?

*FH.* On the order of 10 to 14 inches. More in a wet summer and less in a dry one.

*MWM.* The strip-cutting experiment puzzles me. The yield increase seems small considering that one-third of the total area was harvested.

*FH.* Based on the area cut, the water-yield increase from the first cycle of strip-cutting would be roughly one-third of the first-year increase after complete forest clearing, or between 3 and 4 inches. So the actual increase of just over 1 inch does seem surprisingly small.

There are two explanations for the small increase. First, regrowth was not inhibited on the strip-cutting as it was on the completely cleared watershed, so some transpiration occurred from the cut strips. A second explanation may lie with the cutting configuration. The strip-cutting greatly increased the crown exposure and transpiration rate of trees on the borders of the uncut strips. Water was available for the increased transpiration because roots extend into the wetter cut strips.

*MWM.* So cutting 25 one-acre patches is not likely to produce as much water as a single 25-acre clearcut?

*FH.* Yes, and single-tree selection cutting should be even less efficient — although we have not studied it at Hubbard Brook.

*MWM.* How long will the increased water yields persist?

*FH.* Sprout growth, utilizing previously developed root systems, herbaceous vegetation, and tree seedlings can re-establish pre-cutting transpiration in 3 or 4 years. Our complete forest clearing experiment has provided a dramatic illustration. The last of three annual herbicide applications was made in the summer of 1968. In the 4 years after, regrowth was profuse, and water yield increases nearly disappeared (fig. 2).

Rapid regrowth on the cleared watershed occurred despite 3 years of herbiciding. Natural regrowth occurring immediately after a forest cutting may be even more rapid and reduce the yield increase more quickly. So it is clear that maintaining a water-yield increase will require extra effort. Possibilities include the use of some mechanical or chemical means to hold back regrowth

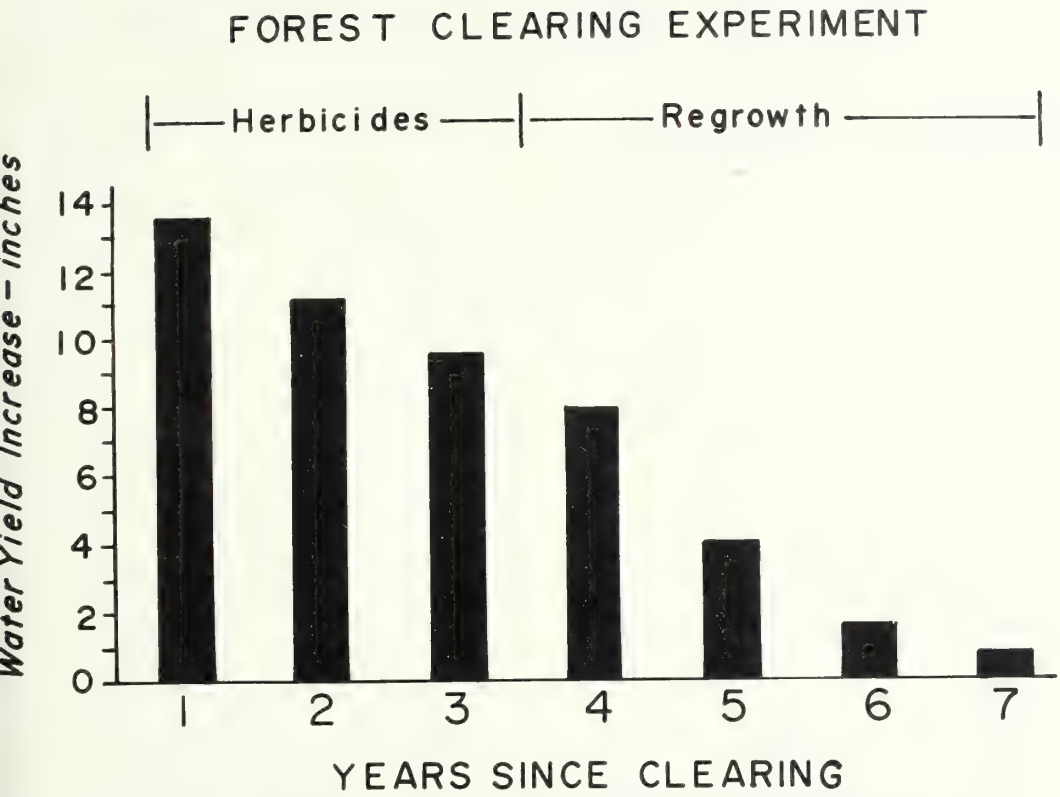


Figure 2.—Results of forest clearing experiment at Hubbard Brook.

or the use of a rotation system whereby some portion of the watershed is always recently cutover.

*MWM.* Will cutting the forest during dry periods cause an immediate increase in streamflow?

*FH.* Our studies at Hubbard Brook indicate that soil-water deficits of 4 inches can occur in dry spells. Since ET from forests is about 1 inch a week, a month with no rain or 6 weeks with 2 inches of rain would produce such a deficit. Cutting when such a deficit exists will nearly eliminate any further ET, but will not provide greater water supply for streamflow. The expected water-yield increase from cutting will not come until after the soil-water deficit has been satisfied by rain, in this case not until there has been more than 4 inches of rain.

*MWM.* Once a sizable soil-water deficit has occurred, is there anything I can do to get more streamflow quickly?

*FH.* We've spent considerable effort on this and have come up with only three possibilities: rain dances, cloud seeding, and paving the watershed.

*MWM.* I'd like to ask about some of the other effects of forest cutting on streamflow. Doesn't increased streamflow mean bigger floods?

*FH.* If the soil-water deficit at the time of a flood is smaller in the cut-over area than in the forest, the streamflow will be correspondingly higher. For the 13 major storms occurring in the first three summers after our clearing experiment, the average increase in stormflow was 0.5 inch and the maximum increase was 1.2 inches. The simultaneous occurrence of a heavy rainfall and a

large difference in soil-water deficit between cut and uncut forest is very rare, we think. Furthermore, seldom would more than 25 percent of a watershed be clearcut at any one time, so the effect would be further minimized. If rain falls when there is no soil-water deficit, there is no difference in streamflow from cut and uncut areas.

*MWM.* What about snow. Doesn't snow melt more rapidly in open areas?

*FH.* Yes, snowmelt runoff was several days earlier in our clearcut and strip-cut experiments. But partial clearing of a watershed has a beneficial effect on snowmelt floods because the melt runoff is desynchronized. Snow is gone from the cleared areas while snow in the forest is still melting. Here, too, the effect is very quickly lost or diluted downstream. Snowmelt floods are regional in nature, and local forest-management activities cannot have any significant effect on them.

*MWM.* It doesn't seem that increased flooding is a problem with cutting. But what about erosion, turbidity, and water temperature changes? Can they be protected against during and after forest treatments?

*FH.* As a precautionary note to any type of watershed treatment, the forest floor must be disturbed as little as possible to maintain its characteristic high infiltration capacity. This precaution is necessary to prevent increased storm runoff by overland flow and to protect against erosion and subsequent sedimentation of streams.

The completely cleared watershed at Hubbard Brook illustrates the protection capability of the forest floor. The experiment did not involve harvesting, so the only disturbance to the forest floor was the slight disturbance during the felling of trees. In the years since cutting, including the 3 years in which there was little or no vegetative cover, the only apparent erosion has been small amounts along streambanks and channels. For the most part, stream turbidities have remained at less than 1 turbidity unit, well within the drinking-water standard of 10 turbidity units.

If timber is being harvested from a watershed, the principal concern is careful location and construction of roads and landing areas as well as necessary maintenance during and after logging operations. By following known precautions when logging the strip-cut watershed, we were able to keep turbidity changes to a minimum. In the 2-year period during and after cutting the first set of strips, only 6 of 147 streamwater samples had turbidity values exceeding the drinking-water standard. The maximum value was 38 turbidity units.

With regard to stream temperature, any cutting that opens up the stream channel to direct sunlight will increase stream temperatures. After our complete forest clearing, summer stream temperatures increased by as much as 11°F. In the strip-cutting treatment we left a shading strip of trees along the stream channel, and summer stream temperatures increased less than 2°F.

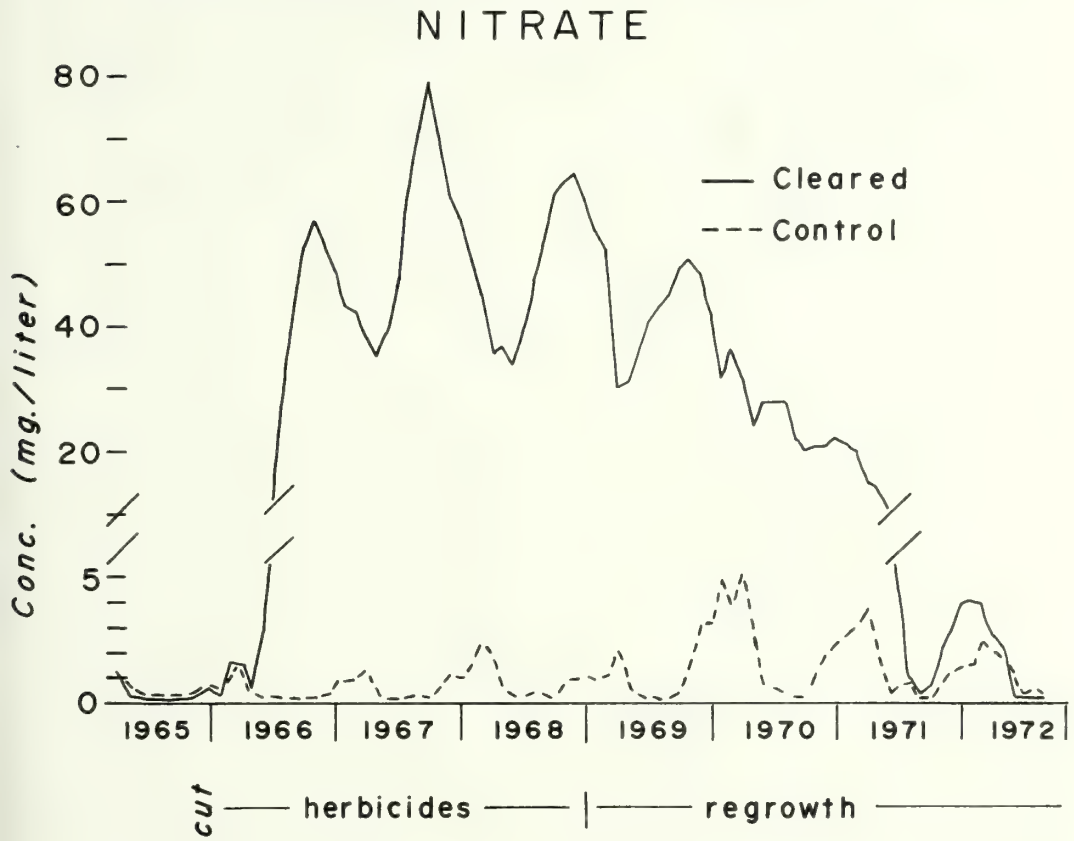
*MWM.* So keeping the loggers out of the stream, taking care of the skidroads, and leaving trees along the channel ought to eliminate these problems?

*FH.* That's right.

*MWM.* I've heard something about dissolved ions increasing in the streams and nutrient loss from the soil after the cutting at Hubbard Brook. What's the story on that?

*FH.* Our nutrient-cycling studies have revealed a less obvious water-quality problem — nutrient leaching after forest cutting. The problem was most clearly demonstrated by the cleared watershed. Blocking the uptake of available nutrients by eliminating nearly all the vegetation, and exposure of the site to greater-than-normal amounts of heat and moisture, caused an increase in nu-

Figure 3.—Nitrate concentrations in streams of completely cleared and control watersheds.




trient ions leached to streams. The nitrate ion was most responsive to forest clearing, and streamwater concentrations rose from a usual value of about 2 ppm for undisturbed forests to a maximum of 80 ppm (fig. 3).

The increase caused nitrate to exceed the drinking-water standard (45 ppm) and also represents a sizable loss of valuable nitrogen from the watershed. Other dissolved ions — including calcium, magnesium, sodium, and potassium — increased from 3 to 20 times as a result of forest clearing.

We have found that less drastic treatments such as silvicultural clearcutting or strip-cutting also increase nutrient concentrations in streams, but to a smaller extent than the complete clearing. For example, in streams draining 8 recent clearcuttings in the White Mountains, the average nitrate concentration was 9 ppm, and maximum nitrate concentration from any clearcut area was 28 ppm. In comparison, streams from undisturbed watersheds located near each of the clearcuttings always had nitrate concentrations of less than 5 ppm. The maximum nitrate concentration in the first 2 years of strip-cutting was 11 ppm. None of the streamwater from timber-harvested areas had nutrient concentrations higher than drinking-water standards. However, we have seen evidence of localized eutrophication of small streams after clearcutting.

Results of nutrient-cycling studies at various locations in the United States are beginning to show that New England may be more susceptible than other areas to the nutrient leaching problem. This may be due largely to our coarse-textured soils and their low ability to hold nutrients, particularly in the absence of a plant cover.

*MWM.* It looks like I will have to worry a little about that nitrogen release; but there's a dilution effect here if only part of the watershed is cut, isn't there?

*FH.* Yes. A rotation system in which only portions of the watershed are cut-over would insure dilution by streams from uncut areas. Also the nitrate concentration in streamwater after cutting should not be a problem if regrowth is allowed, and as long as there is no reason to make the drinking-water standard more restrictive.

*MWM.* But what will happen if I try to keep the area devegetated to keep the water yield up?

*FH.* Then you would definitely have a problem, not only with drinking-water standards but also with eutrophication and loss of important nutrients from the forest ecosystem.

*MWM.* Thinking of trying to maintain an increased water yield, I suppose I could herbicide the area every few years.

*FH.* That might work, although we have no experience with it. Certainly the cost and the possible side-effects of the herbicide would have to be considered carefully. We found herbicide applications on our 38-acre cleared watershed to be expensive and time-consuming.

*MWM.* What about the species of plants? Do any particular species transpire less than others?

*FH.* This is an area of research we are just getting into and know little about. If there are differences, they are small, and we have not measured them yet. ET turns out to be a rather difficult thing to measure with less than 10 or 15 percent error. And differences among full covers of different species are less than this. We have tentative evidence that sugar maple and beech may transpire less than yellow birch. If the difference were 5 percent over a summer, a beech-maple stand might yield twice the summer streamflow of a birch stand. However, this is very hypothetical and certainly is not yet a basis for management.

*MWM.* What about shrubs, grass, or conifers?

*FH.* We don't know anything about ET from shrub or grass covers in the Northeast, nor whether it would be possible to maintain them. But we know that streamflow from a hardwood-forested watershed is likely to be 2 or 3 inches a year greater than that from a conifer-covered watershed. The difference is primarily due to greater interception of snow and rain in conifers in the dormant season. The conifers may also transpire more water than hardwoods, especially in early spring and late autumn.

*MWM.* So getting rid of conifers is the only species change that might be useful. But is that going to increase flow in summer?

*FH.* No, only in the dormant season. You would need a large reservoir to store the extra water if you needed it in summer.

*MWM.* We've spent a lot of time talking about cutting, but I have to be concerned about recreational use and about the aesthetics of my municipal watershed area. Isn't there anything I can do to get more water without changing the appearance of the area?

*FH.* We've spent a lot of time on cutting because that is what we know most about. We don't have any other proven ways to increase water yield at present

There are hormones that can be sprayed on plants to reduce transpiration, but for various reasons they are not yet useful. If a promising hormone is found, we are prepared to test it at Hubbard Brook to see if it can be put to practical use.

*MWM.* My job seems to be getting increasingly complicated. Even though people want more wood and water, they also want to preserve the forest as it is. I don't know how far I can go with timber cutting.

*FH.* Management of forest land certainly is not as simple as it seemed 5 or 10 years ago. The public is much more conscious of the forest resource and has definite likes and dislikes about forest management. Before you embark on a program of forest cutting to increase water yield, you should first investigate the alternatives for obtaining additional water — and the costs. And the dollar costs should not be allowed to totally influence decisions. For example, your water users may not object to paying more for water from other sources if it means they will not have to look at cutover areas on their municipal watershed.

Finally, we recommend that you maintain a close alliance with scientists and other forest land managers. Challenge them for ideas and assistance on how best to manage your municipal watershed.

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# MANAGEMENT IMPLICATIONS OF OTHER HYDROLOGIC RESEARCH IN THE NORTHEAST

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*ABSTRACT.* Research results from a wide array of institutions are reviewed, mostly about the effects of various activities on the amount of water and the timing of its availability; information about the impact on water quality is more limited. Interception effects caused by northeastern tree species and the characteristics and water storage capacities of their associated humus layers are discussed. The significance of the sources of storm runoff and the effects of management of streamside vegetation are also discussed. Fertilizers, road salt, and herbicides may cause local temporary damage; they are chiefly of concern when accidentally introduced into a water body.

THE PURPOSE of this paper is to give an overview of the research programs in watershed management being carried out by the wide array of institutions throughout the Northeast whose efforts have not been covered in other presentations in this Symposium. A wide spectrum of research is included in these programs, and to bring a semblance of common purpose the material will be discussed by subject-matter breakdown; first, research concerned with water quantity and timing as influenced by variation or manipulation of particular portions of the hydrologic cycle, next, research related to water quality, including both natural and man-induced effects.

## EFFECT ON WATER QUANTITY AND TIMING

### *Canopy Interception Effects*

Vegetation covering the land surface influences precipitation as it falls. Forest cover is particularly effective in this respect, and the interception process has been the subject of much research. Water held by trees and evaporated is generally regarded as a loss. Brown and Barker *(1970)* have shown that significantly less throughfall reaches the ground under immature oak stands in Rhode Island than has been reported for other stands of similar species in the Northeast *(Helvey and Patric 1965)*

[1]Research reported from the University of Massachusetts Agricultural Experiment Station is supported by McIntire-Stennis Research Project MS-1.

Interception loss was 10 and 13 percent of gross precipitation in the dormant and growing season; throughfall was 85 percent of gross rainfall during the dormant season and 83 percent during the growing season. However, the 5 and 4 percent of the rainfall that appeared as stemflow in the two seasons reduced the apparent total loss to some extent.

Snow reaching the canopy may be lost by vaporization from tree crowns in central New York even under radiation conditions apparently unfavorable for evaporation *(Eschner and Leonard 1968)* The snow that is removed from the canopy by wind may be vaporized in transit and be lost *(Heisler 1970, p. 43)*, so that simple redistribution is not its only possible fate.

Although increasing density of forest vegetation usually results in increased interception loss, there is some indication that the forest canopy may increase the amount of snow on a site. Measurable condensation or frost formation on coniferous crowns has been observed in central New York *(Eschner and Leonard 1968)* and may be a factor in reducing or modifying morning evaporation rates. Black *(1968)* found evidence that widely spaced evergeens invading pasture land may increase the accumulation of snow on a watershed, increasing the spring runoff volume.

#### Humus Layer Interception and Storage

The surface humus layers developed under forests have long been credited with a considerable sponge-like absorbing capacity of importance in water storage and flood prevention. Recent studies of humus layer characteristics under white pine showed moisture-holding capacity and moisture regimes to be such that only about ¼ inch of rain could be absorbed during the growing season on the average — of limited importance in comparison to moisture storage in the soil profile *(Mader and Lull 1968)*. The same conclusions were reached in studies of the forest floor under hardwood stands in the Northeast. The results of the studies suggest that management of stands to increase forest floor depth for water storage would not be very effective.

#### Soil Frost and Snow Accumulation and Melt

Investigations of the occurrence and depth of soil frost at Cadwell Creek have been made under different forest types and densities by the University of Massachusetts. Previous research in northern New England *(Hart 1963), Pierce 1956, Sartz 1957)* had shown soil frost formation to be negligible in the forest and under a snowpack. The frequency and depth of frost, with consequent possible runoff effects, had not been investigated in southern New England where snow cover may be intermittent. However, during 2 years of investigation of heavily thinned and fully stocked conifer plantations and small openings in central Massachusetts, no soil frost was found because snow cover was persistent through most of the winter *(Wilen et al. 1973)*. Although these results do not preclude the possibility that soil frost in forests may on occasion be an important hydrologic factor in this area, they indicate that the probability is not great.

The research at the Sleeper's River Experimental Watershed in Vermont provided some important results on soil freezing in grass pasture areas *(Dunne and Black 1971)*. Concrete frost occurred in the topsoil in 1967, resulting in low infiltration rates. About one-half of the water produced by snowmelt left the plots as overland flow. Their results suggest that conversion of forests to grass or maintenance of grass pastures to increase water yield is likely to result in formation of concrete soil frost in some years, causing undesirable surface runoff.

The Cadwell Creek research included snow studies that indicated that, while rate of snowpack accumulation and maximum depth and water equivalent were less (30 percent and 15 percent respectively) under unthinned red pine plantations than in the open, the snowpack under the dense conifers did not disappear until 3 to 10 days later than in open areas. Heavily thinned plots in red pine north of unthinned areas trapped snow in a drift adjacent to the edge of the unthinned stand to the south, increasing the stored water equivalent by about 20 percent. The snowpack in these areas also melted somewhat more slowly than that in the open, suggesting that heavily thinned east-west strips in coniferous plantations may have a substantial effect on snow accumulation and melt. These results are in general agreement with previous reports by workers in the Northeast and the Lake States *(Bay 1958, Eschner and Satterlund 1963, Hart 1963, Lull and Rushmore 1960, Weitzman and Bay 1959)* and a recent study by Clausen and Mace *(1972)*.

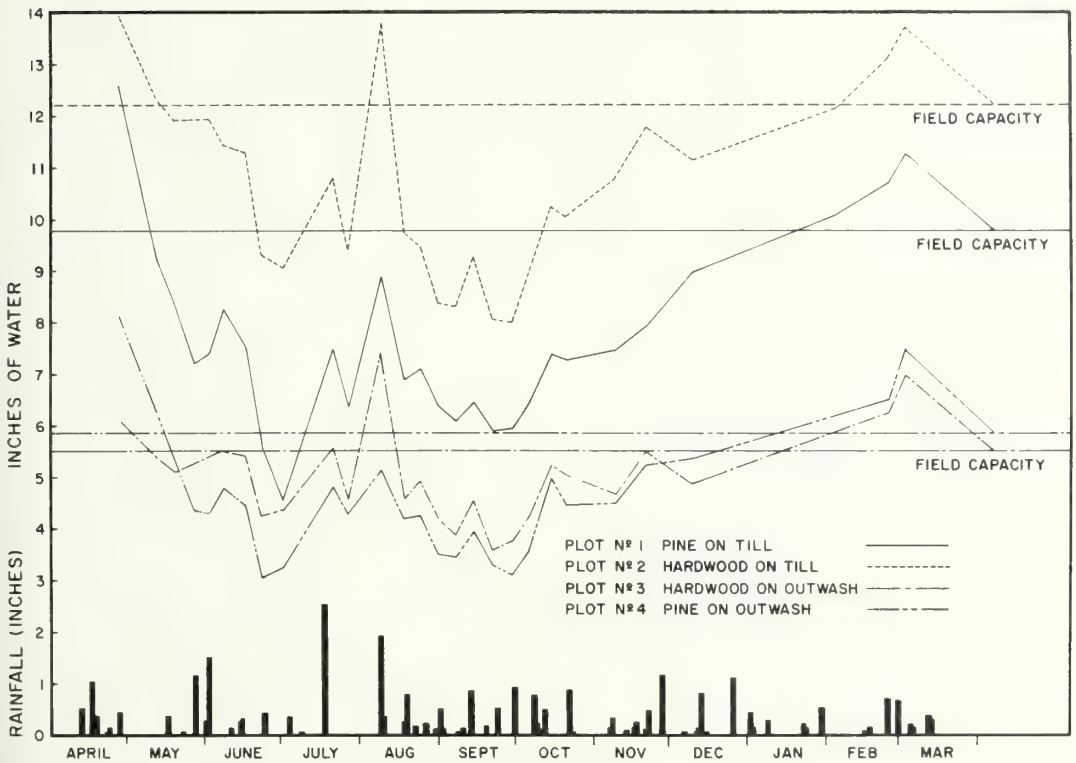
Several modified types of soil-frost measuring devices were tested in these same studies. Small easily-constructed and inexpensive gypsum soil-moisture blocks were found very satisfactory for soil-frost studies *(Wilen et al 1972)* as well as the Fernow-type gage, which was modified to reduce heat conductance into the soil and between layers. A further modification was proposed, which should enable measurement of sub-surface frost below thawed surface horizons. This generally corroborated the findings of Harris *(1970)*, Patric and Fridley *1969)*, and Sartz *(1967)* concerning frost-measuring devices.

#### *Soil-Moisture-Regime Studies*

Soil-moisture-regime studies to compare the hydrologic effects of different cover and soil types have been carried out at the University of Massachusetts. Comparisons of fully-stocked stands of white pine, mixed oak and other hardwoods, and a grassed area *(Affleck 1966, Machno 1966)*, confirmed the theoretical expectancy and observations of Urie *(1959)* that pines dry out the soil by using more water in the spring and retard resaturation in the fall compared to hardwoods because of the presence of foliage on the pines during these periods. The importance of such differences in water use in regard to actual surface or subsurface runoff is highly unpredictable because of the dependence on rainfall. However, Affleck's results on till soils (fig. 1) indicated about an additional 3 inches of storage capacity in 4 feet of soil was created on till or outwash soils by pines, as compared to hardwoods, during periods in early and late spring and mid-summer when substantial runoff likely occurred from the hardwood but not pine sites.

Grass cover seemed more conservative in water use in late summer than either pine or hardwood cover, but did show rapid extraction and creation of available storage capacity in the early spring. Because of soil-texture differences, direct comparisons are not possible; but the sandy soil under grass reached minimum water contents in mid-July and showed a recharge trend thereafter, resaturating to field capacity about mid-October so that subsequent precipitation would have gone into runoff. In early June and mid-August, sufficient rainfall occurred to cause probable saturation of the soil and some runoff. The coarse soils under hardwoods and pines did not reach minimum moisture contents until about the end of September and did not resaturate until at least near the end of November and possibly during the winter. The grass site seemed to have been producing considerable runoff for a period of about 1 month in October and

Figure 1.—Soil moisture measured in 4 feet of profile in four 1/5-acre plots of differing soil and vegetative cover in western Massachusetts. Measured rainfall and estimated field capacity of the soils are shown. (From *Affleck 1966.*)




November, when similar wooded soils were not yet back to field capacity.

Soil-texture differences (fig. 1) seem to have important effects on water yields because of their effects on water-holding capacity *(Affleck 1966)*. The estimated difference between maximum and minimum water content observed in medium-textured till soils to a 4-foot depth was about 6 inches of water under hardwoods, and nearly 8 inches under pine, while on coarse sandy outwash soils the differences were about 4 inches under hardwoods and 5 inches under pine. Though deeper rooting might offset these differences to some degree, the data collected showed small amounts of moisture depletion at lower depths, especially under the hardwood stand; so it appears unlikely that substantial soil moisture storage is created at lower depths. The high levels of resaturation of the outwash soils in midsummer in relation to experimental field capacity measurements and the excess of rainfall over observed soil moisture recharge both indicated probable greater water yield from the outwash soils than from the till soils.

The recommendations to be inferred from these studies are that hardwood stands are preferable to conifer stands for increasing water production from forested areas, differences in runoff resulting from differences in soil-moisture regimes being likely to occur in late spring and in fall in the Northeast. Maintenance or conversion of stands to

hardwoods can often be achieved by silvicultural practices that incur little or no expense. As suggested by previous research *(Metz and Douglas 1959)*, grass cover tends to use less water than forests, especially in late summer, and would probably tend to increase runoff in the fall, but the problems and costs of maintaining such cover versus the benefits are uncertain at present. Recognition of the importance of coarse-textured outwash soils as sources of runoff or groundwater recharge suggests they should be prime areas for acquisition and potential management to increase water yield.

Studies in the southeastern Adirondacks have indicated that soil-moisture recharge in soils of average depth (about 6 feet) is complete by mid-November or early December and is no different from the soil-moisture content of irrigated forest land receiving twice the average amount of growing season rainfall *(Eschner et al 1969)*. The "priming" required by western soils before snow melt runoff can take place in spring *(Stockwell 1965)* is not necessary here. This implies a more immediate response by stream levels to spring's climatic changes such as warm air masses or strong solar radiation.

The efficacy and place of thinnings or partial cuttings as a management tool for influencing soil-moisture regimes to increase water yields has been a recurring question in the Northeast. In general we know that the reduction in crown surface and rooting extent caused by removal of trees will reduce the rate and possibly total amount of water transpired and tend to increase water yields. However, the actual benefit achieved by various levels of cutting in different forest types and climatic and soil conditions is not certain, so investigations are in progress in a number of places in the Northeast.

Studies in central Massachusetts of the effects of thinning levels on soil-moisture regimes and crop-tree growth in 20-1 to 130-year-old white pine plantations *(Hunt and Mader 1970)* suggest that very heavy thinnings can be safely carried out which result in very rapid increases in growth and value of pruned crop trees while reducing water consumption by 1 to 2 inches, or more, during the growing season. The shortening of the rotation and increased crop value seem likely to more than meet the cost of this procedure so that any increases in water yield would be achieved at little or no cost. A related study of tree growth and soil moisture response to thinning levels and fertilization in 60-year-old low-quality second-growth stands consisting primarily of red and black oak and red maple is under way. Results show that in the first 2 years after a very heavy thinning (about 10 to 15 percent of basal area left), soil-moisture deficits at the end of the summer were 3 to 4 inches less in a 42-inch profile than in comparable unthinned stands. In the first year after thinning and fertilization, diameter growth on residual trees (7- to 12-inch diameter range) was about double that in the unthinned stand (about 0.18 vs 0.09 inches).[2] The increase from thinning alone was only about half that of the combined treatment. The response was somewhat greater the second year, thinned stands showing diameter growth increases of about 50 percent over the control, thinned plus fertilized stands about 150 percent (0.1 vs 0.25 inches). There were no significant differences in soil-water deficits between fertilized and unfertilized stands. The economics of the treatments in terms of increased timber values versus costs has not yet been determined.

[2]Francisco Lozano, Univ. Mass. Agric. Exp. Stn. Res. Proj. MS-1.

### *Riparian Vegetation Effects*

The effects of riparian-zone vegetation on soil-moisture regimes and water yields has been an important facet of research at the University of Massachusetts. Removal or deadening of all woody vegetation in the riparian zone of one subwatershed of the Cadwell Creek Experimental Watershed resulted in much higher soil-moisture levels in the riparian zone of the treated versus the control areas. Frequently the increases were from 40 to 75 percent (about 5 inches) in late summer and fall *(Mader et al 1972)*. The differences between treated and control areas were greater nearer the stream than farther away in spite of the fact that higher moisture levels were maintained near the stream in the treated area; this supports the view that movement of water into the riparian zone allows very rapid and sustained water loss from this portion of the watershed and that removal of vegetation in this zone will be more effective in conserving water, per unit area treated, than treatment in other areas. The results also suggest that leaving this vegetation, as is often recommended for stream protection, may result in the loss from this zone by transpiration of increases in runoff produced by treatment of other portions of the watershed.

Results of streamflow studies[3] to evaluate the effect of the integrated management program on the Cadwell Creek subwatershed showed the possibilities of such programs to increase water yields. The treatments, which represented a combination of practices felt to be feasible and practical for actual watershed management, included a commercial logging operation that removed nearly half of the merchantable timber in a pattern of small patch or group cuttings, deadening of all trees by injection in the riparian zone (100 feet in distance or 10 feet in elevation from the stream channel) with removal of merchantable stems during logging, mistblowing of a 200-foot strip adjacent to the stream to deaden lesser woody vegetation, and heavy thinning by injection of the small acreage of plantations occurring on the subwatershed.

Substantial increases in water yield were achieved; growing season increases for the first 2 years after treatment were 35 to 40 percent, increases on an annual basis about 22 percent. Subsequently the increases dropped off gradually but were still 21 percent and 14 percent respectively in the fourth year. Preliminary economic analysis indicated that the value of the water produced far exceeded the cost of treatments. The adverse characteristics of the program were primarily the unesthetic appearance of the deadened trees in the riparian zone, the use of herbicides, and increases in the range and maximums of temperatures in the stream. Logging residuum and logging-road use seemed to draw little objection nor have serious impact on the water quality, and the density of lesser vegetation in the riparian zone seemed to preclude much nutrient loss or resulting water-quality change from the treatments.

The widespread practice of planting conifers on the shores around reservoirs has a high cost in the excessive amount of water removed from groundwater. Forest cover along reservoir shorelines can use 1 to 6 area-inches more water annually than upland forest cover *(Lull and Reinhart, 1967)*.

Studies in New Hampshire of the water lost by evapotranspiration in bushy wetlands *(Hall et al., 1972)* indicated that such areas may use 1.7 times as much water as is lost from open-surface evaporation and that they prob-

[3]Brian R. Mrazik, Univ. Mass. Agric. Exp. tn. Res. Proj. MS-1.

ably can be managed to increase water yields at critical times by use of evaporation suppressants. They also may serve as important flood-control storage systems.

#### *Contributing Area*

The source of streamflow from a watershed at different times and under different physical conditions has received scrutiny recently. Many of the results conflict with traditional ideas of stormflow and baseflow. Some of the studies in New England support the traditional view. In an agricultural area in Vermont *(Dunne 1970)* snowmelt runoff ran over the surface of frozen soil to the channel. This runoff dominated the daily discharge hydrograph and responded to the rate of incoming shortwave radiation. Usually less than 10 percent of the total watershed area contributed storm runoff. Deep permeable soils produced no storm runoff. Overland flow came from small areas of shallow soil that became saturated in some storms. Generally only a small portion of the total drainage area contributed to storm runoff.

#### *Stomatal Control*

For many years the idea of being able to control stomatal diffusion of water vapor has intrigued watershed managers *(Zelitch and Waggoner 1962)*. It is assumed that water loss through leaf pores is controlled by pore size of the individual leaf *(Waggoner and Zelitch 1965)*. There remains the question whether the transpiration loss from a stand would be reduced appreciably by stomatal closure on individual leaves *(Waggoner 1967)*. This question has been explored recently, and both affirmative *(Lee 1967)* and negative *(van Bavel 1968, Idso 1968)* answers were given. Proposed methods of artificial control of stomatal openings are difficult to apply to forests and require the use of compounds that are potentially toxic. The outlook for practical use is not promising.

#### *Wilderness Management*

Increasing public pressure is being exerted on the U.S. Forest Service and state agencies to implement the National Wilderness System or a similar alternative in the eastern United States. Areas of wilderness are proposed for inclusion in the system, but the implications of this action may not be recognized. When extensive areas of relatively stable vegetation are set aside for wilderness, man's activities are sharply restricted. However, changes in the vegetation continue, and in some cases the possibility of catastrophic change increases. In the southeastern Adirondacks over a period of 39 years, the forest density and crown coverage of conifers increased after the cessation of logging and the initiation of effective fire protection, but average annual streamflow decreased more than 7 inches *(Eschner and Satterlund 1966)*. On the Sacandaga Watershed most of this decrease (5 inches) came in the October-to-April dormant season. A late fall windstorm of hurricane force blew down many big old conifers and brought about an increase in the streamflow.

### WATER-QUALITY STUDIES

#### *Water Color*

One cause of impaired water quality is dissolved or suspended organic matter. The presence of beaver dam impoundments on watersheds in the Northeast has increased dramatically in recent years. The role of these and other swampy areas *(Hall et al 1972)* in producing organic compounds is being studied by the University of Massachusetts on the Amherst Watershed.[4] Pre-

[4]B. O. Wilen, Univ. Mass. Agric. Exp. St. Res. Proj. MS-1.

liminary results have substantiated that beaver dams are important in color production, and that removal of the dams and increasing channelization will decrease color levels in water. Indications are that increased rainfall and runoff lessen color by dilution, and that color can be predicted effectively from temperature and rainfall data once the relationships have been established. Further study of the factors producing color and their potential control is under way.

#### *Salt Problems*

The problems of salt, particularly sodium chloride and calcium chloride, which are used widely to melt ice and snow on streets and roads in the Northeast, have been of concern in recent years because of possible deleterious effects on vegetation and pollution of groundwater. Some states apply as much as 20 tons per mile on a traffic lane, the average is about 300 pounds. The fate of the applied salt is not well known, but several accumulation sites have been suggested: the street itself, roadside soils and groundwater, roadside vegetation, and drainage channels. Studies in New Hampshire *(Rich 1968)*, Maine *(Hutchinson 1968)*, and Massachusetts *(Holmes and Baker 1966, Motts and Saines 1969)* have all shown increased salt in roadside areas and the presence of at least localized areas with sufficiently high levels to cause toxic effects on plants by either sodium or chloride accumulation, and also to cause serious increases in salt content of groundwater. In a suburban Syracuse stream, winter chloride contents as high as 11,000 ppm have been observed *(Hawkins and Judd 1972)*. Chloride content has been observed to be higher in areas where calareous sediments are found *(Mairs 967)*.

Motts and Saines *(1969)* emphasized he need for study of septic tanks, air pollution, and drought periods as causes of increased chloride content in groundwater supplies. Salt accumulation in small lakes may cause density stratification and changes in the biota and physical characteristics of the water body *(Hawkins and Judd 1972)*. Restriction on use of road salt and strict control of septic tank standards and density are needed on areas that contribute to municipal reservoirs, private wells, or groundwater recharge areas.

#### *Nutrient Problems*

Addition of nutrients or use of other chemicals on a watershed carries with it considerable risk that the material may find its way into the stream or groundwater. Nitrates and phosphates have already been identified as serious water polluters. When an area is covered by forest or other stable vegetation, the result of any application is likely to be different from that on an agricultural or otherwise disturbed area. For example, some workers feel that in forest fertilization, nutrients are being added to natural ecosystems in which they will be absorbed into nutrient cycling systems that will prevent any substantial losses out of the system *(Weetman and Hill 1973)*. If the chances of serious stream and groundwater pollution through fertilization are slim because the forest floor is a good natural filter, there are still possibilities of unfavorable changes in other components of the ecosystem, which should be explored because they are not now clearly understood.

Loss of nitrates and phosphates from fertilization of agricultural lands is both a problem to the farmer and a source of nutrients introduced into water supplies. Nitrate and other ions from very high density feeding operations and waste-disposal and septic-tank or sewage effluents are also serious sources of contamination. The forest has been proposed

by Sopper and his co-workers *(Sopper 1971)* as a potential environment suitable for disposal of certain effluents containing organic and inorganic wastes. These wastes may be effectively absorbed and cycled by the vegetation as a nutrient source and thus not cause water pollution or eutrophication while simultaneously recharging groundwater supplies. Studies at Connecticut on disposal in a red pine plantation of poultry manure and associated waste at high rates *(Stephens and Hill 1971)* caused considerable buildup of nitrogen in the soil and accelerated movement in percolating waters so that some potential for pollution can occur. This is particularly true for coarse outwash soils, which are prime groundwater recharge areas.

In addition to the deliberate fertilization of watershed land, there are many elements that are added naturally or inadvertently. It has been found that 13, 38, and 151 pounds of sulphur per acre per year were deposited by rainfall in rural, urban, and industrial locations in Wisconsin, with an overall state average of 27 pounds per acre per year *(Hoeft et al 1972)*. In the same study, the amount of ammonium nitrogen and organic nitrogen deposited by precipitation was highest in spring and lowest in winter and was higher in areas adjacent to barnyards. Nitrate-nitrogen addition was fairly constant for all locations and was slightly lower in winter. Total N ranged from 12 to 27 pounds/acre/year, with an overall state average of about 18 pounds.

Preliminary results of a study of lead outputs from a watershed ecosystem indicate that the primary exit for this element is streamflow *(Rolfe and Eddington 1973)*. Apparently in the urban part of the watershed, much lead particulate is deposited on paved surface and is quickly washed off during storm periods, resulting in a rapid increase in the amount of suspended lead in the stream. This does not occur in the rural-agricultural part of the watershed. However, only 2 to 3 percent of the lead input is leaving through the water system; apparently a large buildup of lead is taking place on the watershed, possibly in stream-bottom sediments, soils, and the biota.

Nitrate production from devegetated natural systems has been demonstrated by the Hubbard Brook experiments *(Borman et al 1968)*. Another source of nitrates is being investigated by Peterson *(1968)* at the University of New Hampshire, where alder communities are being studied. Older stands of alder appear to produce much more inorganic nitrogen than younger stands, suggesting that they may contribute to increased nitrogen in stream water and cause eutrophication.

The pathways in natural waters of nitrogen and phosphorus — common and important fertilizer elements — have been the subject of considerable research, and the literature on the fate of N and P in water and sediments has recently been reviewed by Keeney *(1973)* and Syers et al *(1973)*. They point out that the effect of sediment properties, lake morphology, and physical and chemical characteristics have an important bearing on the pathways and rates of N and P turnover. Suspended particulate material from erosion may act as a carrier for fertilizer elements as well as iron, manganese, and other elements. When deposited as sediments they may act as a sink for large amounts of chemical elements. Limnologists are concerned about the forms and location of N and P in water, their rates of movement, and impact on the natural eutrophication process *(Werner 1973,* Frink's *(1971)* studies in Connecticut indicate that sediments do act as a sink for nutrient elements and reduce eutrophication of associated surface

waters. The short- and long-range effects of this process need to be evaluated to determine the importance of this aspect of the need for control of sedimentation.

### *Interpretation of Research Results*

The research we have been discussing parallels much that has been presented earlier. It is important to emphasize certain points, from the watershed manager's view, whose significance may be somewhat obscure.

Conifers are able to intercept more snow and rain, and to extract more water from the soil than hardwoods over a range of soil textures in the Northeast. Maintaining hardwood stands or converting conifers to hardwoods is desirable if a high rate of water yield is an objective of management. Manipulation of cover type and strip cuttings in conifer stands have been shown to influence the patterns of snow accumulation and melt considerably, but the practical importance of such practices has not been demonstrated. Efforts to increase forest floor depth for additional water storage for flood control do not appear to be justified.

The low storage capacity of coarse-texture outwash soils makes them naturally high producers of runoff and groundwater recharge. Because of their excellent drainage these soils have been widely used for waste disposal and development in spite of the fact they may transmit pollutants readily to streams and groundwater. Recognition of their importance suggests that they should be prime areas for acquisition and management for water yield.

Several studies suggest that very heavy thinnings or cuttings can produce substantial increases in water yields for several years. These cuttings may be revenue-producing or increase growth and shorten rotations to such an extent as to be economically feasible on the basis of timber values alone. Woody riparian vegetation appears to be a very large user of soil moisture, and substantial water-yield increases may result from its control or conversion to lesser vegetation types. Current practices advocating the preservation of undisturbed strips along streams to protect them is not consistent with maximum water production.

The use of chemicals for stomatal control or other anti-transpirant effects remains a clouded subject. Reductions in transpiration have been reported, but potential toxicity, difficulty of application, and doubtful cost/benefit relations make the practice unpromising at present.

Treatment of large areas of watershed as wilderness, currently advocated by several interest groups, may not be consonant with management for maximum yields or protection of the areas. On land long-undisturbed use of water by vegetation may be maximized and water yield reduced, while hazards of windthrow, insect, disease, or fire damage may increase.

The sources, characteristics, and control of water color problems have not yet been elucidated but are of growing importance as less favorable water-supply sources must be tapped. Beaver dams, increasing rapidly in number in the Northeast, and natural swamps seem to be prime sources of color. Methods to minimize problems from these areas are needed.

A number of recent studies have demonstrated widespread salt contamination of surface and groundwater supplies, as well as soils, from road-salting. Runoff from fertilized agricultural land, septic-tank effluents, and air pollution from automobiles and other sources are actual or potential degrading influences on water supplies by addition of nitrates, phosphates, sulfates, lead and other undesirable materials. Control

of these contaminants is needed on areas that contribute runoff to municipal reservoirs or recharging groundwater supplies, especially on coarse-texture soils that allow rapid transmission to groundwater and do not filter effectively. Although forest fertilization or disposal of wastes as fertilizers on forests may be safe, effective, and desirable on some sites because of the forest's ability to filter out and cycle the nutrients, overapplication on coarse soils is hazardous to groundwater.

Although overland flow is virtually unknown from the Northeast's well-forested watershed areas, there is evidence that overland flow is likely to be an important source of stormflow from open and agricultural land. This form of water movement is likely to be especially important in winter when the soils of open areas are likely to be frozen. Much attention has been focused on the sediment produced by this overland flow as a form of pollution. There are indications that its role is much more complicated than we have supposed, and is not fully understood. Sediment in water may carry adsorbed nutrients, among other things, and may serve as a source or a sink of troublesome materials in streams and lakes. This relationship merits further study so that its dangers may be realized and its potential advantage exploited.

The wide spectrum of research projects under way suggests a growing appreciation and concern for maintaining or enhancing both quantity and quality of our water-supply sources. The value of the research is already evident, and energetic application of the principles evolved can be very worthwhile to municipal watershed managers.

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# THROUGHOUT THE NORTHEAST – AN OVERVIEW

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*ABSTRACT.* Forest watershed research has shown how management practices in the Northeast affect water quality (sediment, temperature, and nutrients), water yield, and stormflow. It has demonstrated how water quality can be protected and overland flow controlled. It has not yet shown how vegetation management can be used in a practical way to achieve the big potential for increased water yield.

THIS YEAR we are celebrating the 50th anniversary of the Northeastern Forest Experiment Station. This is also the 40th anniversary of forest watershed-management research in the East — at the Coweeta Hydrologic Laboratory in the mountains of North Carolina. Though Coweeta is not in the Northeast, we welcome its research contributions. In many respects, high-elevation Coweeta resembles the Northeast more than it resembles much of the South.

What do we have to show for these years of effort? I think we can show a great deal. We have even changed many of the basic concepts of the forest-water relationship. The research done and accomplishments made have been well covered in the papers presented at this symposium. Besides the work at Coweeta, we have heard about work on experimental watersheds at the Fernow Forest in West Virginia, at Penn State, at Hubbard Brook in New Hampshire, on municipal watersheds at Baltimore and Newark, and other pertinent research at the universities and elsewhere.

To summarize and to highlight, as I see it, research has:

1. Determined sources and amounts of turbidity from forest activities.
2. Demonstrated methods to keep soil erosion and the resulting turbidity under control.
3. Determined streamwater temperature and nutrient problems and measures to control them.
4. Determined that overland flow in the forest is an exception rather than the rule.
5. Determined that vegetation management can substantially influence water yield.
6. Demonstrated that timber can properly be harvested from many municipal watersheds.
7. Made a beginning in development of prediction equations and models.

8. Provided a better understanding of fundamental hydrologic processes.

But research has *not:*

9. Demonstrated how the big potential for increased water yield can be achieved within constraints of ownership patterns, economics, aesthetics, etc.

And in another area, we have not had much research on the effect of recreational activities on water, though much of the research accomplished has some bearing on problems in this field.

## DISCUSSION

I want to say a little more about each of these major research accomplishments.

### *1. Sources and Amounts of Turbidity*

Over the years, most research on the quality of water from forested watersheds has been directed at turbidity, caused mostly by soil particles in the water. The Northeast is generally fortunate: because of climate, vegetation, and soil characteristics, its erosion and sediment problems are less acute than those in most other regions of the country.

In the undisturbed forest, erosion rates are almost universally low, and the quality of the water produced is high. When the forest is disturbed, as by timber harvesting or other operations, the picture may change drastically. Research and general observation have amply demonstrated that it is not the cutting of trees, but the baring and compaction of mineral soil incident to removal of products that causes major erosion and sediment damage. This observation may seem simple and self-evident, but it is often ignored in present-day arguments about forest practices.

### *2. Keeping Erosion under Control*

Guidelines have been developed to help watershed managers operate on lands they control without generating turbidity problems. However the impacts of land use on watershed lands — both forest and nonforest — that the manager does not control may be serious. This problem calls more for educating and providing incentives for operators and landowners than for developing new technical know-how.

### *3. Streamwater Temperature and Dissolved Nutrients*

I doubt that these were even recognized as problems when watershed research began at Coweeta, or even later at the Fernow or Hubbard Brook. But research, and probably astute observation in its absence, has shown that cutting the forest can cause appreciable rises in stream temperatures. These may be harmful to cold-water fish species. But considering the relative exposures of water surfaces in impoundments and streams, I doubt that there is any great effect on water as supplied to consumers. In any event, the simple expedient of reserving all or most of the trees immediately adjacent to watercourses apparently solves any problem there might be.

Interest in and study of nutrient concentrations in streamwater, as affected by forest practices, is of recent origin. Clearing the forest and repressing regrowth in New Hampshire caused alarming increases in nutrient concentrations — especially concentrations of nitrate-nitrogen. Regular timber-harvest clearcutting in New Hampshire caused smaller but still appreciable increases. The few studies made in other locations all showed relatively small effects. Considering drinking-water standards, we conclude from the evidence to date that tree cutting in most of the Northeast will not cause nitrate-nitrogen concen-

trations to even approach the danger level. And in New Hampshire and similar areas, no problem should arise so long as most of the watershed is not heavily cut at the same time.

On a related subject, research has shown that carefully planned and conducted applications of herbicides to watershed lands can be made with only a minimal danger of pollution. However, in this environmental age, this may not be good enough. Any slight pollution may be considered too much. And in some situations even the idea of applying such chemicals to water-supply areas may not be acceptable to the public.

#### *4. Overland Flow the Exception*

Years ago, all stormflow was often considered to stem from overland flow, often ambiguously labeled surface runoff. However, as early as 1943, Hoover and Hursh noted at Coweeta that overland flow does not occur under natural forest conditions. It is now generally recognized that subsurface flow, not overland flow, is the important process in the forest. This recognition has had a major impact on our concepts of erosion and stormflow in the forest. However, even though most flow is subsurface, much of it can still reach the stream soon enough to contribute to damaging high flows when flood-producing storms occur.

#### *5. Increasing Water Yield*

Annual precipitation in the Northeast averages about 41 inches. Probably a little more than half of this is used up where it falls (in evapotranspiration). Can we do anything to reduce this onsite use and thus increase the water yield for domestic and other uses? Research has shown that this can be done; but because of environmental and economic restraints, such management is rarely attempted.

As Douglass and Swank said, we have for the Appalachian Highlands the most complete and detailed information available anywhere on the response of streams to management of their watersheds by man. Their formulas for determining the amount and duration of water-yield increases after cutting provide a long-needed yardstick. Our knowledge for areas in the Northeast outside the Appalachian Highlands is not so complete and detailed, but we are still in pretty good shape to make reasonable predictions about the effects of vegetation removal on water yield. In brief, heavy cutting of a forested watershed provides substantial increases, but these increases diminish rapidly with regrowth. For any given area, increases are about in proportion to the intensity of cut. As a corollary, establishment of full forest cover on bare or sparsely vegetated land will reduce water yields.

We have relatively little information about the effect of conversion from one type of cover to another. However, there is evidence that conversion of hardwood forest to grass will increase yield by several inches, and that conversion from hardwood forest to pine will decrease yield. Even with our limited information, I think these research results provide useful guides to management. For instance, when the pine plantation on your municipal watershed matures and is harvested, consider replacing it with something else.

#### *6. Timber Can Be Harvested from Municipal Watersheds*

Over the years, many people have feared that harvesting timber on municipal watersheds would greatly increase turbidity and might cause reduced flows in dry spells. With careful planning and supervision, it is possible to log without undue erosion and turbidity. And timber harvesting will increase rather than decrease water yields, especially in the drier seasons of the year — though if only a portion of the

watershed is logged at one time, the amount and duration of increase may not be enough to help much with water-supply problems.

More recently, fears have been expressed about pollution by nutrients as a result of timber harvesting. Nutrient pollution should pose no problems, at least if only part of the timber on the watershed is logged at any one time.

#### *7. Prediction Equations and Models*

The development of prediction equations and models helps bridge the gap between research and application. The equations by Douglass and Swank, relating water yield to forest cutting, mark a start in this direction. Another start is a mathematical model for streamflow being developed at Hubbard Brook. I expect that in the next few years we will see many more developments in this direction.

#### *8. Fundamental Processes*

We have discussed mostly the results of empirical experiments because these seem more easily applied to the evaluation of management practices. But the study of the fundamental processes in forest hydrology is perhaps even more important, because without a thorough understanding of these processes, we can hardly hope to manage intelligently. Much has been done — and much remains to be done — in the study of solar radiation and how it affects evapotranspiration, of the interception process, of the paths of subsurface flow, and of other aspects of forest hydrology. As our understanding improves, we will be better able to develop prediction equations and mathematical models and to apply research results in solving the everyday problems of municipal-watershed management.

#### *9. Increasing Yields within Existing Constraints*

It has been amply demonstrated that cutting the forest can increase water yield — by as much as 16 inches in the first year after one treatment at Coweeta. Why then haven't we seen widespread application of this practice? There are many reasons, including economics, the temporary effects of cutting alone, aesthetics, resistance to use of herbicides, and land-ownership patterns. I don't know whether we can ever achieve any appreciable part of the potential for increased yield within these formidable restraints. But I do have a few suggestions:

- Aim for a positive approach. Rather than proposing destruction of the forest, advocate management to favor mountain laurel, to provide recreational blueberry picking, or to increase diversity in the landscape by providing some grassy park-like areas.
- Study ways to repress vegetation with common salt, heat-torch, defoliants, and other methods less objectionable than conventional herbicides.
- Study methods of type conversion that cause minimum site disturbance.
- Study the water use and methods of establishing and maintaining types of vegetation — mountain laurel, blueberry, grass, and others — that may use less water than the ordinary high forest.
- Study possibilities for initiating treatments in water-short periods. If your reservoir is low in the spring, you may have supply troubles in the summer even if summer precipitation is near normal. May or June treatment might help here.

Research has shown a number of possibilities for protecting water quality and improving yield. Undoubtedly many questions remain to be answered. This meeting, bringing together the watershed scientists and managers, should help both groups do a better job in the future.





# CURRENT MANAGEMENT PRACTICES ON THE BALTIMORE MUNICIPAL WATERSHEDS

*by* BRENT A. HARTLEY, *Watershed Manager, Water Supply, Treatment and Pumping Division, Bureau of Operations, Department of Public Works, Baltimore, Maryland.*

*ABSTRACT.* The City of Baltimore supplies water to an estimated 1.5 million people in a 215-square-mile service area. To meet the water needs of this area, the City has developed three sources of supply and maintains three municipal watersheds. Management of Baltimore's watersheds is complicated by the fact that the City owns less than 6 percent of the total drainage areas of the two upland sources of supply. In addition, management of Baltimore's watersheds differs from that of many others in the Northeastern United States due to the fact that we harvest timber on our watersheds and operate our own sawmill. We have also tried to provide recreational opportunities compatible with our primary function of supplying the city's filter plants with an adequate supply of high-quality raw water.

THE CITY OF BALTIMORE supplies water to an estimated 1.5 million people in a 215-square mile service area consisting of Baltimore City and parts of Anne Arundel, Baltimore, and Howard Counties. In addition, Carroll County, which borders in part on Liberty Reservoir, purchases raw water from the City. Average daily consumption in 1970 was 245.37 million gallons per day. Water use was as follows: residential or domestic use, 143.93 million; large industrial use, 68.03 million; commercial use, 33.41 million.

## SOURCES OF SUPPLY

To meet these demands, the City has developed three sources of supply: Gunpowder Falls (safe yield, 148 million gallons per day), the North Branch of the Patapsco River (safe yield, 95 million) and the Susquehanna River (initial capacity, 150 million).

### The Gunpowder Supply

There are two impoundments on Gunpowder Falls. Loch Raven, a 2,400-acre terminal reservoir, has a 223-square-mile drainage area and an initial capacity of 23 billion gallons. Prettyboy, a 1,500-acre upstream reservoir, has a drainage area of 80 square miles and an initial capacity of 20 billion gallons. Prettyboy Reservoir provides storage to supplement the supply at Loch Raven. When the water storage at Loch Raven drops to 87 percent of capacity, two 36-inch needle valves at Prettyboy Dam are opened, and water is allowed to flow down the bed of Gunpowder Falls into Loch Raven Reservoir.

Baltimore City owns less than 6 per-

cent of the 303 square miles in the Gunpowder Falls drainage area above Loch Raven. The City owns and manages 5,600 acres of forested watershed land surrounding Loch Raven Reservoir and 5,880 acres of forested land surrounding Prettyboy Reservoir.

Land use on the Gunpowder watershed is estimated as follows: 20 percent forested, 40 percent agriculture, 40 percent residential-commercial.

### *The Patapsco Supply*

Liberty Reservoir, on the North Branch of the Patapsco River, is a 3,100-acre terminal reservoir with a drainage area of 164 square miles and an initial capacity of 43 billion gallons. Here too, the City owns less than 6 percent of the total watershed. City holdings are limited to approximately 6,100 acres (9.53 square miles) of forested watershed lands surrounding the reservoir itself. There is no upstream reservoir on the Patapsco supply.

Of the 164 square miles in the Liberty watershed, approximately 20 percent is forested, 40 percent is in agriculture, and 40 percent in residential-commercial use.

### *The Susquehanna Supply*

The Susquehanna supply is presently used in time of drought or emergency only.

Unlike the Gunpowder and Patapsco, which are both gravity sources of supply, water from the Susquehanna must be pumped to reach the City. Susquehanna water flows by gravity from the intake located above the Philadelphia Electric Company's hydroelectric dam at Conowingo, Maryland, to the Deer Creek Pumping Station, approximately 3 miles below Conowingo. Deer Creek Pumping Station then pumps the water over a high ridge near the town of Level. From here the water flows by gravity to the Montebello Filtration Plant in Baltimore.

The intake structure has an initial capacity of 250 million gallons per day and an ultimate design capacity of 500 million. The Deer Creek Pumping Station has an initial capacity of 150 million and an ultimate design capacity of 243 million. Connecting the Intake and the Montebello Filtration Plant are over 38 miles of tunnel and pipeline ranging in size from 144-inch to 96-inch diameter.

## FORESTRY

In 1948, the City recruited a woods crew and purchased heavy equipment, including a sawmill, to salvage timber from the area to be flooded by the new Liberty Dam. Before this time, no timber had ever been cut by the City on any of its watershed land. Management practice was limited to fire protection and reforestation of land formerly used for grazing and agriculture.

When the clearing for Liberty Reservoir was completed, attention was shifted to the forests surrounding the other two reservoirs. The experience gained and equipment used at Liberty was put to work removing overmature and defective trees and — stand conditions permitting — undesirable species. The objective was to maintain a residual stand of approximately 3,000 board feet per acre of high-quality timber.

After the initial sanitation cut we adopted the selection system of management and cutting. Although this is not the most economical system of cutting to use, it leaves sufficient cover to protect the watershed and maintain the aesthetic value of the forests while providing a continuous source of timber to meet the City's limited lumber needs. Trees to be cut are selected and marked by our watershed forester. Trees are cut when at their highest value, and the

healthy young trees of desirable species are left to continue protecting the soil and to produce future timber crops.

Our woods crew, which consists of twelve men, processes the timber from the felling of trees to the production of lumber at the sawmill. Weather and ground conditions permitting, these men work in the woods. In inclement weather and when necessary to meet our lumber commitments, these same men operate the sawmill.

Logs are sawed into lumber for use primarily as sheeting and shoring for trenches for underground utilities being constructed by the City. We also produce all of the hubs and stakes used by City survey parties, along with other specialty items such as fence posts, guard rail posts, pier timbers, etc. Only slabwood is sold to the public. All other products are consumed by the City and are accounted for through a system of interdepartmental work orders and debit tickets.

Prices charged are as follows:

| | |
|---|---|
| (1) Rough lumber and timbers (2″ sheeting thru 12″x12″x18′) | $125.00/MBF |
| (2) Finished lumber | $175.00/MBF |
| (3) Blocking — ranges from | |
| 1″x6″x12″ to | .05 each |
| 6″x6″x16″ | .90 each |
| (4) Surveyor's hubs (2″x2″x12″) | .10 each |
| (5) Surveyor's guard stakes (1″x2″x24″) | .18 each |
| (6) Wedges | .20 each |
| (7) Slabwood | |
| | $2.00 per ½-ton pick-up |
| | 4.00 per ¾-ton pick-up |
| (8) Sawdust | Free for taking |
| (9) Shavings | Free for taking |
| (10) Locust posts | $1.50 each |

Forest-related income in 1972 amounted to over $80,000, and since 1955 has totaled over $1,900,000. Sawdust and shavings not used by City school and recreation agencies for mulch, jumping pits, playgrounds, etc., was given away. Thinning of pine plantations yielded 521 long cords of pulpwood and added $14,588 to the forest-related income for the year.

To facilitate logging and other forestry operations and to provide access to remote areas of the watersheds for fire-fighting and other emergencies, we have constructed over 200 miles of permanent unpaved woods roads. These roads were laid out and constructed in strict compliance with the recommendations of the U.S. Forest Service.

In 1969, the City invested $46,000 in a new automatic sawmill to replace the old belt-driven mill, which had been in service since 1955. The new mill produces between 500,000 and 750,000 board feet of lumber per year and requires five fewer men to operate than did the old mill.

Careless logging practices on municipal watersheds can be detrimental to water quality. However, by locating, constructing, and maintaining our logging roads in accordance with the recommendations of the U.S. Forest Service, erosion and sedimentation have been minimized.

All roads are laid out with the lowest possible grade (allowable 10 percent maximum) on side-hill slopes away from streams. Culverts are installed where the roads cross the smaller streams, and at major stream crossings we have constructed fords, using concrete paving slabs salvaged from abandoned roads on the watershed. Cross drainage is provided in the form of water bars (based on the rule of thumb: water-bar spacing = 1,000 feet/percent of grade) by making shallow sweeps with a dozer blade.

After completion of logging in a compartment, the slash is lopped and placed on the skid trails in such a way as to divert surface runoff out of the

trails thereby preventing erosion, logging roads are regraded, water bars rebuilt, and the landings and portions of the road having grades approaching the 10 percent maximum are revegetated. Roads are checked annually and after major storms, to make sure the drains are clear and the roads are passable in case of emergency.

## MAINTAINING WATER QUALITY

Maintenance of water quality in our reservoirs also requires good sanitation practices on our own property and the surveillance of tributary streams to determine the quality of water entering the reservoirs.

To simplify trash clean-up and sanitation, we try to channel visitors to a few areas where we provide parking, comfort stations, and trash cans. Comfort stations have sealed concrete holding tanks to prevent pollution of the water supply. Fishermen, hikers, and picnickers who venture into the more remote areas of the watersheds where we have no comfort stations or trash cans are a problem. The containers in which they bring their food, drinks, bait, etc. are often left strewn along the roads and shoreline. Boat fishermen too, contribute to the litter problem. However, from time to time, ecology-minded citizens volunteer to clean up this litter. We usually accept their offers and assist where possible.

### *Stream Surveillance*

Streams tributary to our three impounding reservoirs are sampled and tested regularly to detect any marked change in the quality of water entering the reservoirs. All sewage-treatment plant effluents and most streams are sampled monthly. However, those streams having relatively small sparsely inhabited drainage areas are checked only quarterly. Samples are collected by watershed personnel and analyzed by chemists and biologists of the Water Division's Purification Section. Should the lab find a marked change in the quality of any sample, that stream is resampled immediately. If the second sample shows similar abnormality, we work our way upstream where practical, searching for the source of pollution. Samples are tested for pH, color, turbidity, dissolved solids, alkalinity, chlorides, total coli, fecal coli, dissolved oxygen, total phosphates, nitrates, NH3N, ABS, and trace metals.

In April of this year a new problem came to light when the monthly sample taken of the Hampstead Sewage Treatment Plant (300,000 GPD activated sludge, extended aeration sewage treatment plant) effluent was found to contain 50,000 chlorella algae cells per ml. Subsequent samples, taken weekly for 14 weeks, contained concentrations ranging from 4,000 cells/ml. to 200,000 cells/ml. and averaged over 55,000 cells/ml.

Algae is first detected in the treatment units themselves and rapidly multiplies in the holding or polishing pond, which has a 3-day flow-through time.

The nutrient discharge from the Hampstead plant is also high. For the five samples taken of the effluent between January and May 1973, total phosphates ranged from 20.0 ppm to 60.5 ppm and averaged 31.6 ppm; nitrates ranged from 10.0 ppm to 33.6 ppm and averaged 26.1 ppm.

Though the State of Maryland has no regulations governing the discharge of nutrients into state waters, we feel that the quantities being discharged from this facility could and should be reduced. Consequently, a letter was written to the State Department of Natural Resources requesting that corrective measures be instituted.

We intend to continue our fight for tertiary treatment for any future sew-

age-treatment plants built on the Gunpowder and Patapsco watersheds. The Hampstead plant should serve as an example of why this is needed.

### MAINTAINING AND IMPROVING WATER YIELD

Fortunately precipitation and water yield on the Baltimore watersheds are generally adequate to meet the current water demand of the area served. Manipulation of vegetation to increase water yield on the 6 percent of the total watershed of either upland source of supply which we control would be of little consequence. It appears, however, that the change from agricultural and forest use to residential and commercial use of the 94 percent of the watersheds under private control is influencing streamflow regimen by concentrating stormflow timing.

Although we have no program for improving water yield, we are concerned with the effects of changing vegetative types and land uses on the watershed and are cooperating with the Northeastern Forest Experiment Station in conducting related research on three subwatersheds on the Liberty Reservoir watershed.

### WATERSHED PROTECTION

To protect our reservoirs and watershed lands and to regulate recreation, we have adopted rules summarized in "Regulations Governing the Loch Raven, Prettyboy and Liberty Reservoirs."

To enforce these regulations we have six watershed patrolmen. They hold special police commissions issued by the Maryland State Police, wear uniforms, and are armed. They patrol the watersheds in 4-wheel-drive vehicles equipped with two-way radios. The reservoirs are patrolled in outboard motorboats, which are also radio equipped.

Until this year, repeated efforts to enlarge the six-man patrol force have failed due to budget limitations. In 1972 the U.S. Environmental Protection Agency conducted a survey of the Baltimore water-supply system in accordance with provisions of the Interstate Quarantine Regulations. Thanks to recommendations by EPA contained in the report on this survey, eight new watershed patrolman positions were approved by the Department of Finance for fiscal 1974. In addition, signs are posted to remind the public that swimming, wading, ice-skating, camping, firearms, fires, vehicles (except on paved roads), dumping, and boating, except by permit, are prohibited.

All the foregoing of course protects only the City-owned portion of the watersheds. By 1971 it became obvious that the time had come for the City to speak out about the other 94 percent.

On 15 March, 1971, the Board of Estimates of Baltimore City (Mayor, President of City Council, City Solicitor, Comptroller, Director of Public Works) approved a "Policy for Future Development within the Gunpowder and Patapsco Watershed", providing definitive guide lines covering five major areas of concern: zoning, building, pollution control, appropriation of water, and recreation.

Briefly summarized, the City's position on these subjects is as follows:

*Zoning.* — The City encouraged Baltimore and Carroll Counties to adopt low-density residential zoning as a minimum around the periphery of the reservoirs for a distance of at least 1 mile where feasible.

*Building.* — Building on the watersheds should conform to local and state laws regarding storm water runoff, soil erosion, and sedimentation. Regulatory agencies should exercise strict inspection controls to limit any possible pollution of the reservoirs from storm runoff, soil erosion, and sedimentation.

*Pollution control.* — Citing pollution from sewage-disposal systems and effluents from industrial plants, the City urged construction of interceptor sewers to carry sewage out of the watershed areas.

*Appropriation of surface water.* — The City will not permit any private developer to appropriate water from tributaries within the Gunpowder and Patapsco watersheds for any purpose.

*Recreation.* —Any expansion of recreational facilities must be weighed against the pollution and erosion that may result.

The City has the right to prevent appropriation of water and to regulate recreation on its reservoirs and watershed property. However, we must depend on the governments of Baltimore and Carroll Counties to exercise good judgment in regard to the zoning, building, and pollution-control recommendations.

## RECREATION

According to a recent study *(Corbett 1970),* Baltimore City allows as great a variety of recreational activities on its reservoirs and watershed lands as any municipality or private water company in the Northeast. Activities permitted include: boating, boat and bank fishing, picnicking, hiking, horseback riding, bow-and-arrow hunting at Prettyboy and Liberty, skeet shooting, and golf.

With the exception of the boating and boat fishing concession at Loch Raven (fig. 1), which is operated by the Baltimore County Department of Recreation and Parks, and the skeet-shooting range and golf course also at Loch Raven (fig. 2), which come under the jurisdiction of the Baltimore City Department of Recreation and Parks, all recreational activities on the three watersheds are managed and controlled by the Watershed Section. However, the Watershed Section retains control of the land occupied by the Loch Raven Fishing Center, skeet range, and golf course and reserves the right to take appropriate action in case of mismanagement of the land.

A good example of why we feel that

ure 1.—Fishing from shore or boat is owed in the recreational areas on Loch ven Reservoir. For those who do not wish row, electric motors are available for rent.



Figure 2.—Pine Ridge Golf Course, built on watershed property, attracts many golfing enthusiasts. Loch Raven Reservoir is in the background.



it is imperative that control of land management remain in the hands of the watershed superintendent occurred a few years ago at the Pine Ridge Golf Course at Loch Raven, when we learned that a mercury-base fungicide was being used there in quantities considered potentially dangerous. We notified the Department of Recreation to cease using this product immediately. They complied.

#### *Boating*

Boating at Liberty and Prettyboy reservoirs is controlled by the City Watershed Section. Holders of the 700 annual permits are allowed to use either or both reservoirs for boating and fishing between sunrise and sunset from 15 March through 30 November. No inflatable or collapsible boats, sailboats or power boats are allowed. Propulsion must be by rowing or by battery powered electric outboard motor. Canoes and kayaks are permitted only at Prettyboy.

Each boat is assigned a number, and two color-coded stickers bearing this number are issued with each permit. This sticker and the assigned number in numerals 2½ inches high must be displayed on the port and starboard quarters of each boat. The permit itself must be carried by an occupant of the boat and be shown to watershed personnel on request. By rotating the sticker color annually, we can tell at a glance whether or not a boat belongs on the lakes.

Income from the sale of permits by the City is deposited in the General Fund. None of this money is returned to the Watershed Section for improvement of the facilities. Loch Raven Fishing Center Rates for 1973 were:

Daily fee for fishing from boats, 50 cents for those 14 and over.

Daily rowboat rental, 2 hours or less, $2; full day, $3. No more than three fishermen to a boat (57 boats available).

All-day electric motor rental, battery included, $5.

Launching fee for daily use of private boat, $1.50.

Season-long launching permit, $25.

Season fishing permit, $15.

Season boat-docking permit, which enables one to keep his boat on the reservoir, $20 (90 docking spaces).

In 1972 the Center operated at a profit of $7,000 - $8,000 which went into a capital-improvement fund for the Center.

#### *Fishing*

Bank and boat fishing are permitted at all three reservoirs. No fee is charged by the City for fishing, but fishermen over 16 years old must have a state fishing license. However, the Baltimore County Department of Recreation and Parks, which operates the fishing center at Loch Raven, charges a fee to fish from boats there. No wading is allowed, and fishing is prohibited from shore where banks are steep or rocky or otherwise considered to be hazardous.

The major problems generated by fishing are the litter thrown overboard and left strewn along the shorelines by thoughtless fishermen, plus the fact that few fishermen return to the boat dock areas to avail themselves of the sanitary facilities provided there.

#### *Picnicking*

Free picnic facilities are provided at all three watersheds and are available on a first-come basis. Although fires of any description — including charcoal grills — are prohibited, the facilities are heavily used, especially on weekends and holidays.

We have built over 200 picnic tables for use in these picnic areas, using lumber milled from timber cut on City watershed lands. Comfort stations, also built by our own forces, are located at

or within easy walking distance of each area.

### Hiking

Hiking on our 200-mile woods road system is becoming increasingly popular, not only for individuals and family groups, but also for large groups as well. The local chapter of the Sierra Club and the Maryland Physical Fitness Commission conduct several organized hikes annually.

### Horseback Riding

Horseback riding is permitted, but only on the woods roads. Riding is not permitted in areas where the public normally congregates. In the beginning, riders were few in number — mainly neighboring property owners who owned their own mounts. Now, however, a number of privately owned stables have opened on property adjoining ours. Elaborate facilities have been built to house large numbers of horses, but little land is available for riding trails. Consequently, increasingly large numbers of riders are flocking to our woods roads, and our problems with them are increasing.

When the roads are dry, the horses' shoes break the soil surface and leave a trail of pulverized dirt, some of which is washed into the reservoirs and tributary streams when it rains. When the roads are muddy, the hoofs leave holes that hold water and are difficult to drain. Another problem stems from the riders' tendency to ride single file down the center of the road, wearing a depression in the road, which becomes an avenue of erosion during heavy rain.

Other aspects of horseback riding that create problems include: riding and washing horses in the reservoirs and tributary streams, urination and defecation by horses on roads and in streams, failure to stay to woods roads, and short-cutting on steep slopes between woods roads.

### Hunting

Hunting of any description is prohibited at Loch Raven. However, hunting is permitted at Liberty and Prettyboy only with bow and arrow. Firearms are prohibited because they present too great a hazard to the safety of our visitors, our neighbors, and our own personnel. State Fish and Wildlife Administration officers assist in enforcing our ban on firearms.

### Future Recreation Considerations

In considering requests for new recreational activities on the reservoirs and/or municipal watershed lands, several questions must be carefully considered:

1. Will the proposed activity adversely affect water quality?
2. Will the proposed activity adversely affect watershed lands?
3. Is the proposed activity safe for participants?
4. Will the proposed activity endanger others on and near city property?
5. Will the proposed activity require new or enlarged facilities now or at a later date?
6. Will the proposed activity conflict with other activities already permitted?
7. Are other sites available where the activity can be conducted?

## PUBLIC RELATIONS

Realizing the importance of making the public aware of the problems associated with protecting the reservoirs and watershed lands, we accept all invitations to speak to students, sportsmen, and civic and fraternal groups.

Hundreds of students, ranging from kindergarten to college, visit the watersheds annually. Each group is met by

one of our supervisory personnel, who speaks to them and answers any questions they may ask. More formal presentations are made at area colleges.

## LONG-RANGE MANAGEMENT PLAN

No drastic change in present management policies is anticipated for the foreseeable future. However, more attention will be directed toward locating and reporting sources of sediment and other pollutants entering the reservoirs from the privately owned portions of the watersheds. We also plan to continue resisting the efforts of pressure groups to turn the reservoirs and contiguous watershed property into gigantic playgrounds. We plan to continue harvesting and milling watershed timber and hope to embark on a pulpwood operation to harvest the estimated 30,000 cords available through plantation thinning and the harvesting of mature Virginia pine stands.

Should funds become available, we would recommend that the city assist our farmer neighbors in the disposal of barnyard waste and drainage, a major source of pollution on the watersheds. This assistance would be in the form of the loan of heavy equipment and manpower to operate it.

## MANAGEMENT PROBLEMS

Many of the problems we face in managing the Baltimore watersheds are complicated by the fact that the city owns less than 6 percent of the total watershed of both the Gunpowder and Patapsco supplies and none of the Susquehanna watershed. We are therefore dependent on the cooperation of other governmental agencies in protecting our water supply on the 94 percent of the watersheds over which we have no control.

For example, we must rely on the planning and zoning agencies of neigh-

Figure 3.—Changing land use patterns.
*A*, a former golf course now becomes a r
source of erosion and runoff for the munici
watershed manager to worry about.
*B*, impervious areas in the watershed draina
increase as agricultural lands go out of p
duction.
*C*, suburban development can create seri
sedimentation problems if control measu
are not instituted. Sediment-laden stormf
runs directly to the storm sewer inlet. Flo
eventually deposited in a reservoir fee
stream.









Figure 4.—Nutrient loading and resultant algae populations generated at this waste-treatment plant may lead to algae problems in the downstream water-supply reservoir. Some type of tertiary treatment is needed to alleviate these problems.

boring counties to consider the impact on the watershed and water supply of new development. Domestic sanitation problems, such as failing septic systems, are referred to the local health agencies for correction, and industrial effluent or practices potentially harmful to the water supply are reported to the State Department of Water Resources for corrective action. Erosion and sedimentation problems must be reported to county and state sediment control agencies for action.

Each year more and more of the privately owned watershed lands are being converted from farm, forest, and pastureland to residential developments, industrial parks, shopping centers, etc. (fig. 3). According to the Soil Conservation Service, erosion on lands being so converted is about 10 times greater than on land in cultivated row crops, 200 times greater than on land in pasture, and 2,000 times greater than on land in timber *(Soil Conservation Service 1970)*. Developers are simply not following basic principles of erosion and sediment control. The resultant sediment not only reduces the storage capacity of our reservoirs, but also carries with it fertilizers, pesticides, and other chemical pollutants that lower water quality (fig. 4).

## SEDIMENTATION SURVEYS

Sedimentation surveys were conducted by the Soil Conservation Service at Loch Raven and Prettyboy in 1943 and 1961. The 1943 survey of Loch Raven determined that the annual rate of sediment accumulation was 0.618 acre-feet per square mile of drainage area. Eighteen years later, in 1961, the annual rate of sediment accumulation was found to have been reduced to 0.187 acre-feet *(Holeman 1955)*.

The 1943 survey of Prettyboy Reservoir found that the annual rate of sediment accumulation was 0.699 acre-feet per square mile of drainage area. By 1961 the annual rate of sediment accumulation had been reduced to 0.391 acre-feet.

According to the Soil Conservation Service report on the surveys, the reduction in sediment accumulation was attributed primarily to the large acreage that went out of agricultural use into

residential and other nonfarm uses and to the adoption of soil conservation measures on much of the remaining farmland. Had the transition from agricultural use to residential and commercial use been more abrupt, consisted of larger projects that left large areas without plant cover for extended periods of time, and been closer to the reservoirs, the sediment accumulation rate would probably have increased. However, the changeover was limited mostly to residential construction some distance from the reservoirs and caused very little disturbance to soil and grass. In addition, the forested municipally owned watershed lands surrounding the reservoirs trapped some of the sediment.

Since the 1961 survey, development in the counties, especially Baltimore County, has been on a much larger scale. Housing developments consisting of hundreds of home sites, apartment complexes, shopping centers, and huge industrial parks are being constructed closer to the Loch Raven Reservoir and along tributary streams.

Sediment Control Legislation recently enacted by the State, and subsequently by the counties and Baltimore City, is not being as rigidly enforced as we in the water-supply field would like. Sediment-control procedures are included on all developers' plans, but are not always implemented. In addition, tropical storm Agnes, which struck the Maryland area on 22 June, 1972, dumping up to 14 inches of rain, caused unprecedented flooding and heavy erosion.

As expected, the sediment survey conducted at Loch Raven in 1972-73 by the Soil Conservation Service found that the sediment accumulation rate there had increased markedly. The review draft of the report stated that "during the 11-year period between the 1961 and 1972 sediment surveys of Loch Raven Reservoir, sediment deposits increased 114 percent or from .187 to .401 acre-feet per square mile as a result of increased development within the watershed." The review draft contained the following recommendation: "Because of the rapid increase in the sediment accumulation in Loch Raven Reservoir, it is strongly suggested that strict sediment control procedures be implemented in all future developments; and efforts be made to increase good conservation practices on all farms and woodland in the watershed."

### SANITATION SURVEYS

Sanitary surveys were conducted on all three watersheds in 1970-71 to determine the quality of water in the watersheds. Sanitarians walked the streams tributary to the reservoirs from mouth to source looking for sources of pollution.

Agricultural pollution was found to be the most prevalent. Problems cited included overgrazing, lack of good soil conservation practices, barnyard drainage, and little if any animal waste removal procedures. Industrial discharges and disregard for soil conservation practices and regulations by developers and builders were the second major pollution sources noted in these surveys. Failing septic systems, raw sewage effluents, and privies within 100 feet of the streams were found to be few and were generally located in rural towns.

The surveys found that there was no existing public health hazard from the water being drawn out of the reservoirs which is treated, filtered, and chlorinated before being delivered to the consumer. However, pollution was found to occur in the tributaries in the form of fecal coliform pollution, biochemical oxygen demand (BOD) overloading and excessive siltation. It is believed that the natural physical and biological processes at work in the reservoirs are sufficient to diminish most of these pollutants.

## WATERSHED STAFF

Operation and maintenance of Baltimore's three municipal watersheds is the responsibility of the general superintendent of watersheds (watershed manager). His staff includes an assistant superintendent of watersheds (assistant watershed manager), a watershed forester and three watershed maintenance supervisors (one for each watershed). Other employees include a maintenance mechanic foreman, 6 watershed patrolmen, a principal clerk, and a 42-man labor force, 12 of whom are assigned to the logging-sawmill crew.

### *Duties of Watershed Manager*

Baltimore's watershed manager is responsible for directing and supervising all activities connected with the operation, maintenance and administration of the city's watersheds, dams, reservoirs, and related impounding facilities, including: reforestation; timber-cutting; sawmill operations; lumber disbursement; road-building and maintenance; enforcement of sanitary regulations; enforcement of watershed regulations; control of recreational activities; maintenance and repair of equipment; ordering of equipment, materials and supplies; negotiating for the purchase of any land and/or rights-of-way necessary within the watershed areas; and attending all meetings and handling all correspondence related to the watersheds. He is also responsible for inspection and maintenance of the 38.4-mile Susquehanna River Raw Water Conduit, appurtenances, and the intake structure at Conowingo.

### *Handling Personnel*

Our policy of "treating our employees as we would like to be treated", coupled with our hiring practices, have resulted in good supervisor-employee relations and extremely few problems. Many of our men are career employees and several newer employees are relatives or friends of these men.

Unlike some other agencies in the Department of Public Works, none of our laborers are hired through political influence. In fact very few are even city residents. Most of our employees live in the vicinity of the watershed to which they are assigned. Wherever possible, vacancies are filled by local residents, and preference is given to qualified applicants recommended by our employees.

All 55 employees are known and addressed by name, and outstanding performance is always acknowledged. Our men are conscientious, reliable, hard-working individuals who still believe in giving a day's work for a day's pay. This makes our job a lot easier.

## RELATIONS WITH MUNICIPAL AUTHORITIES

Despite the fact that we are a city agency, we have surprisingly little contact with elected city officials. When we do hear from them it is usually in regard to special privileges sought by a constituent (usually recreation oriented).

Inquiries received and/or correspondence forwarded to us for reply are processed promptly. If our reply is negative, we include our reasons for making such a decision. In so doing we often point out considerations overlooked by the official. Generally speaking, we recommend the open, honest approach in dealing with elected officials.

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## APPENDIX

*(Exerpts from Baltimore County Sediment Control Manual)*

### *Procedures for Incorporating Erosion and Sediment Control in Construction and Development Plans*

Under this sediment control program, the following procedures are provided to assist land owners, developers, engineers, county agencies and contractors in the planning and construction stages of projects. These projects include residential, commercial and industrial subdivisions, schools, highways, recreation sites and other large scale construction where sediment and erosion problems are anticipated.

Mechanics within the County Organization to incorporate erosion control procedures in subdivisions and other construction plans:

1. Prior to any development or construction, optional discussions between developers, builders, contractors, engineers or architects with Baltimore County and the Baltimore County Soil Conservation District are available. Technical advice concerning sediment control measures and other information can be given at these sessions.
2. Individual building permits for residential housing, where a public works agreement is not involved, will be processed for sediment control recommendations and enforcement entirely within the Building Engineer's Office.
3. With regard to subdivision processing, general sediment control advice will be given at the time of the Joint Subdivision Committee Review. A member of the USDA, SCS, representing the Baltimore County Soil Conservation District will be assigned to assist the County at these reviews. A grading plan in conjunction with all sediment control plans will be necessary. A grading permit will be required of the developer and/or owner prior to any grading, including the stripping of topsoil if sediment control measures are recommended. The Public Works Agreement will be revised to include a paragraph with sediment control requirements.
4. The Developer's and/or owner's consulting engineer will provide sediment control drawings which may or may not be a part of the grading plan. The technical guidelines in conjunction with this program should be used in preparation of plans. These plans will be reviewed and approved by the Developers Design Approval Section of the Bureau of Engineering. Further assistance may be obtained through the Baltimore County Soil Conservation District. Comments in written form will be transmitted through the Bureau of Public Services to the developer and/or owner. Some sediment control provisions may be part of the contract specifications as in highway construction. Industrial, commercial, etc., building permits will also be subject to the Sediment Control requirements and procedures.
5. Where sediment control measures are necessary, no grading permit or building permit may be released until sediment control plans are approved. The Buildings Engineer and the Department of Public Works will have to coordinate their efforts to assure proper operation in this area. Also, no record plat may be recorded until sediment control plans are reviewed and approved.

6. Agencies such as the School Board and the Department of Recreation and Parks may provide their own sediment control measures in conjunction with the Soil Conservation District or they may call on the Department of Public Works for assistance.

Other areas of construction such as County highways and buildings are expected to incorporate erosion control features within their specifications using the technical guidelines prepared in conjunction with this program.

7. During the construction stage the Buildings Engineer, the Department of Public Works or the Soil Conservation District will be available for technical consultation.

However, only three (3) men are assigned to inspection of grading and erosion control measures in all of Baltimore County.

# CURRENT MANAGEMENT PRACTICES ON THE BETHLEHEM MUNICIPAL WATERSHEDS

*by* JOHN C. ANSPACH, R.P.F., *City Forester, Department of Public Works, Bethlehem, Pennsylvania.*

*ABSTRACT.* Bethlehem, Pennsylvania, derives its water from two watersheds located in the Pocono Mountains, 30 miles north of the City. The Wild Creek and Tunkhannock drainage areas measure 25,500 acres, of which the City owns 72 percent. Water from the forested watersheds does not require filtration and flows by gravity through a 23-mile transmission line to a service area of 90 square miles with a population of 105,000. The watersheds and the management practices used on them are described, including use of watershed lands for recreation and educational purposes.

BETHLEHEM, PENNSYLVANIA, is located 60 miles north of Philadelphia in the center of the Lehigh Valley metropolitan area. For many years the Lehigh River was the city's main water supply, but in the mid-twenties it became obvious that, because of increased pollution of the river, a better water supply should be located. This supply was found in the Wild Creek drainage, located in Carbon County, approximately 30 miles north of the city.

In 1938 construction was started on a dam across the creek, a chemical treatment plant near the dam, and a 23-mile transmission line to the city. In 1941 the new water supply was inaugurated.

The watershed contains two impounding reservoirs: Wild Creek reservoir, with a capacity of 4.1 billion gallons, and Penn Forest reservoir, built upstream to retain the water that was normally lost over the Wild Creek spillway. Its capacity is 6.5 billion gallons. The total water surface of the two lakes is 765 acres. The reservoirs are fed by 10 streams.

In the late forties a second watershed was developed to back up the Wild Creek supply in years of drought: the upper Tunkhannock Creek, located in Monroe County, approximately 12 miles northeast of Wild Creek. When needed, water from the Tunkhannock Creek watershed is diverted to Wild Creek by means of a 9.1-mile gravity-flow transmission line.

## THE WATERSHEDS

The watersheds are owned by the Bethlehem Authority, which is the legal owner of all the real estate and improvements in the watersheds as well as in the city pertaining to water collection, treatment, and distribution, and wastewater treatment.

The City leases the right to use and operate these facilities and pays a yearly rental to the Authority. The lease agreement stipulates that the City of Bethlehem employ a professional forester for the management of the watersheds.

Two features of the Bethlehem water supply are worth mentioning. First, Wild Creek water does not require filtration. Basically it is rainwater, very soft, with a low alkalinity and a pH in the 6.2 to 6.6 range. The bacteria count of the raw water is very low. The only problem is turbidity, which averages 4 Jackson turbidity units. This factor may eventually impel the City to construct a filtration plant.

Second, the water flows from the watershed to the city by gravity; no pumping is required. From the northernmost lake in the Tunkhannock Creek watershed to the southernmost customer in Hellertown, the distance is 46 miles. This gravity flow is possible because of a 1,580-foot drop in elevation; but two tunnels had to be constructed in the transmission main. A small section in the Bethlehem service area, on South Mountain, is served by a pumped high-pressure system.

The ownership of land in the catchment area determines to a great extent the quality of the water. Ideally all land use in the watershed should be controlled by the water utility. Of a total of 25,526 acres of catchment area, the city owns 18,387 acres or 72 percent (table 1). Acquisition of additional acreage is being considered to protect the city's water interests.

The Wild Creek watershed is hilly, and the soil is susceptible to erosion when not protected by vegetation. The drainage area is almost totally forested (98 percent). The city-owned lands — 10,891 acres — are 100 percent forested.

The Tunkhannock Creek watershed, on the other hand, is flat, and there is little danger of erosion. In this watershed, 1,417 acres are cleared for farming. The watershed area is 88 percent forested. The city-owned properties are 95 percent forested. Where farming practices do not create turbidity in the Tunkhannock watershed streams, the fields are rented to a commercial farming company.

## WATER SERVICE

Bethlehem's water-service area includes not only the City proper but also several of the surrounding boroughs and townships. The total service area amounts to 90 square miles, with 105,000 customers.

Water for domestic purposes accounts for 20 percent of the total volume used in the district (table 2). The average daily flow from watershed to service

Table 1.—Areas of the Wild Creek and Tunkhannock Creek watersheds owned by the City of Bethlehem, 1973

| Watershed | Total watershed area | City-owned land | | |
|---|---|---|---|---|
| | | Inside watershed | Outside watershed | Total |
| | Acres | Acres | Acres | Acres |
| Wild Creek | 13,726 | 10,891 | 1,818 | 12,709 |
| Tunkhannock Creek | 11,800 | 7,496 | 1,508 | 9,004 |
| Total | 25,526 | 18,387 | 3,326 | 21,713 |

Table 2.—Percentages of total volume of water transmitted to service area by different categories of use, City of Bethlehem, 1972

| Use | Volume |
|---|---|
| | *Percent* |
| A. Domestic | 20.2 |
| B. Commercial | 6.9 |
| C. Industrial | 49.8 |
| D. Other | 0.3 |
| E. Bulk sales to other suppliers | 0.4 |
| F. Unmetered use and leakage | 22.4 |
| Total | 100.0 |

area in 1972 was 26.2 million gallons. The projected requirements of the system are 29 million gallons per day for 1975 and 35 million for 1980.

## WATERSHED STAFF

The watershed work force at the present is 23 men, including the city forester and his assistant (fig. 1). A regular work crew, under the supervision of the foreman, is made up of five woodsmen I to carry out routine watershed maintenance and development work. This involves logging, road-building and road-maintenance work, planting seedling trees in the watershed, building maintenance, etc.

Performing more sophisticated work are five woodsmen II who may, for instance, be scheduled for maintaining boundary lines, reading piezometers, planting large street trees in the city, and operating special equipment such as hydroseeders, rotobeaters, and forest fire-fighting equipment. The two heavy-equipment operators and the garage mechanic are classified as woodsmen III.

The three treatment plant operators are usually scheduled on day shift; they perform specialized duties within the plant and on the watershed.

The watershed patrolman works full time on sanitary and security patrols. There are two assistant patrolmen who also may be assigned woodsman II work.

The forest technician works directly under the forester and carries out all watershed technical fieldwork. He is in charge of all planting of seedling trees in the watershed and shade trees in the city.

The city forester's duties involve normal daily supervisory and administra-

Figure 1.—Organization chart for the City of Bethlehem Bureau of Water, Division of Collection and Treatment.

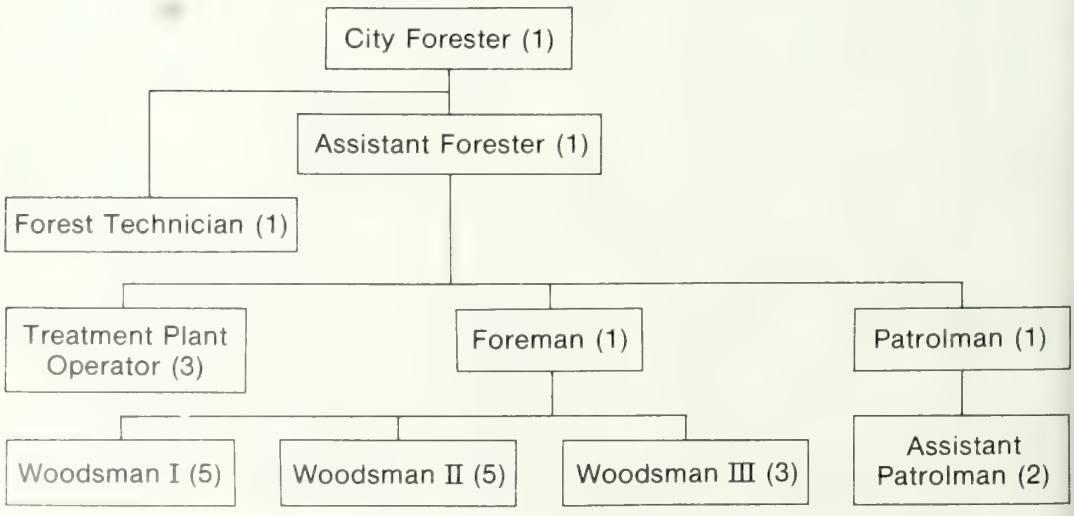


Figure 2.—Wild Creek reservoir and intake tower. The burned area at left was reforested immediately after the fire.





Figure 3.—The Wild Creek lookout tower built by the City of Bethlehem to aid in detection of fires on watershed property. Through cooperation with State fire towers, complete surveillance of the entire watershed in obtained.

tive tasks as well as the planning for watershed developments in the future. The assistant forester supervises the routine daily operations of the watershed.

## FORESTRY PROGRAMS

### *The Reforestation Program at Wild Creek, 1963-68*

In 1963 a forest fire burned 2,300 acres of prime watershed forest land bordering the Wild Creek reservoir. This burnt area included 20-year-old spruce and pine plantations, which were a total loss (fig. 2 and fig. 3).

The burnt area was reforested in a city-conducted operation in 1963-68. The watershed staff was temporarily increased from 6 to 32 men. These crews were equipped with chainsaws, a front-end loader, a timber skidder, and trucks. The reforestation project was financed by Bethlehem Authority and coordinated by the city forester and the assistant forester.

The reforestation work consisted of

salvaging 1 million board feet of burnt sawtimber, chipping all fire and logging debris, stabilizing eroding soils by hydroseeding, and planting 600,000 tree seedlings.

After the reforestation project was completed, city council agreed to maintain a watershed work force of 25 persons for watershed development work.

### *Timber Harvesting Practices*

The timber-harvesting practices applied in the watersheds since 1963 have consisted of work by city logging crews and commercial logging in piecework and stumpage sales.

It should be pointed out, however, that only a small portion of the timberstands in the watersheds are classified as mature (table 3). In the Wild Creek watershed, only 42 acres in the white pine-hemlock type are classified as sawtimber.

In the same watershed, 3,500 acres (30 percent of the total timbered area) are stocked with large pole-size timber in which a selective type of cutting might also produce small dimension logs. Nevertheless a start has been made with selective cutting operations or sanitation cuttings removing mostly dead and diseased timber. In the 1969-73 period, 437 acres were so treated. The selective cuts were carried out in compartments close to some of the important feeder streams and bordering on one of the lakes.

Because of the hilly topography in the Wild Creek watershed, harvesting operations close to watercourses and lakes are carried out by the watershed logging crew. No timber was sold on the stump in Wild Creek because poor logging practices by contractors could cause turbidity in the streams.

On the other hand, stumpage has been

Table 3.—Forest type areas, special land use areas, and lake areas in the Wild Creek Watershed, City of Bethlehem

| Forest type | Size class (dbh) of dominant and codominant trees | Area |
|---|---|---|
| | *Inches* | *Acres* |
| Mixed oak | 8–14 | 2,995 |
| | 4–8 | 3,445 |
| | <4 | 3,128 |
| Aspen — gray birch | <4 | 36 |
| Oak — pitch pine | 8–14 | 493 |
| | 4–8 | 668 |
| | <4 | 217 |
| White pine — hemlock | 14> | 42 |
| | 8–14 | 10 |
| Plantations | 4–8 | 133 |
| | <4 | 308 |
| Nonproductive forest land, understocked areas | | 77 |
| Noncommercial forest land, well-stocked but inaccessible | | 235 |
| Special use areas (picnic areas, rights-of-way) | | 157 |
| Wild Creek and Penn Forest reservoir | | 765 |
| Total | | 12,709 |

sold in the Tunkhannock Creek watershed, where the flat topography caused little concern for turbidity.

In watershed timber cuttings, the skidding of logs is a critical operation, and for the city's watershed logging crew a small open track-type timber-skidder with a built-in logging arch was selected. The damage to the logging area, we found, was considerably less than that caused by rubber-wheeled skidders.

### *Plantation Management*

From the start of the Bethlehem municipal watersheds in 1941, seedling trees have been planted every spring to reforest unproductive fields. Once all available land was reforested, an annual tree-planting program was continued to replenish burned-over and understocked areas.

Including a "Green Foot" tree-planting operation by city volunteer forces in 1963, following the disastrous fire, over 1 million seedlings have been planted in the watersheds.

In addition, seedling trees have been planted in a scrub-oak conversion project. The unproductive scrub oaks were pushed aside by bulldozer and rootrake and replanted with commercial timber species such as red pine, Japanese larch, black cherry, and European alder. The results of this conversion have been very satisfying, and so far 210 acres of plantation have been established. In 1968 the cost per acre averaged $67.

The Norway spruce and red pine plantations established in 1941 have now reached pulpwood size. In 1963 they were found to be overstocked and stagnating in growth. A plan of plantation thinnings was developed, and every fall approximately 20 acres of plantations are thinned. The evergreen boughs are sold to Christmas-green dealers, and the trunks are shipped to a pulpmill.

## WATERSHED PROGRAMS

### *Experiments to Reduce the Color of Tunkhannock Creek Water*

One problem of the Tunkhannock Creek water is its color. At several points of low elevation in the watershed, clear water of unexcelled quality bubbles up through layers of white sand. However, once this water has drained through the swamps into the creek, it shows a high color level.

It is assumed that in the poorly drained Tunkhannock Creek area, because of the acid parent material and acid-tolerating vegetation, the normal decomposition of plant debris is interrupted. Humic acid is formed, the stain of which is chiefly responsible for the color of the Tunkhannock Creek water.

To remedy this color problem, two watershed experiments have been carried out. One field experiment involved the application of alkaline cement-plant stack dust on a 15-acre lake. The second experiment dealt with channeling a swamp for faster draining. Both experiments resulted in negative answers, and the problem of colored water has not been resolved.

### *Work Conducted for Improving Water Quality*

Throughout both watersheds, streams are periodically checked for fallen logs and other obstructions. In several locations rhododendron and other vegetation that crowds the streambanks have been removed.

The banks above the 14 miles of shorelines of both reservoirs are planted to a 100-foot-wide evergreen belt to hold the soil on the steep slopes and to prevent leaves of the surrounding hardwood forest from blowing into the water. Hemlock and spruce are the most effective species.

## RECREATION

The forests, streams, and reservoirs of the city-owned lands in the Wild Creek and Tunkhannock Creek drainage areas have potential recreational values. This potential, however, is restricted by the fact that the city does not filter its water. The forest soil and humus layer, as well as the water storage reservoirs, act as a natural filtration plant. For this reason the 756 acres of lake area and the surrounding safety zone of 1,389 acres are fenced off to the public. Allowing recreation on the reservoirs would necessitate filtration. A conservative estimate for a filtration plant would be $20 million.

Because of the lack of sanitary facilities and limited staffing, overnight camping is not permitted on the remaining 19,568 acres.

Vehicles are not allowed on the forest access roads and fire trails because unlimited use would create a serious road-maintenance problem.

On the other hand, the city's watersheds are open for public hunting under the regulations of the Pennsylvania Game Commission.

Watershed roads and trails are open to the public for hiking and skiing. The public is also encouraged to use the three picnic areas, two of which are equipped with restrooms. Camping is permitted at one location on city land outside the catchment area.

Opening up of the nearby Beltzville reservoir in 1971 for total recreational use has eased the pressure for boating and fishing on the city's reservoirs.

The Pocono International Raceway, located in the Tunkhannock Creek catchment area, has caused increased public pressure in that area.

Considering the proximity of the watersheds to major highways, such as Interstate 80 and the northeast extension of the Pennsylvania Turnpike, heavier demand may be expected in the future.

Notwithstanding the restrictions on the watershed use because of sanitary reasons, the city operates its water-collection areas under the concept of multiple land use, and recreation is one of the recognized types of land use.

## PUBLIC RELATIONS PROGRAM

Since its founding, the Wild Creek watershed has enjoyed the community's confidence. This has resulted largely from the emphasis that those in charge have given to the image of the watershed's green forests, clean air, and pure water.

In the later years it was found, however, that few people were aware of the true functions and services conducted in the watershed.

To make this information available to a wider audience, the city forester's office has initiated the following programs:

- A 20-minute movie called "Wild Creek" was produced, in color and with sound. This movie has been shown on the local educational television programs and is used regularly by the Bethlehem Area School District.

  It has proved to be a very effective public relations tool.
- Talks with slides and the film are available for service clubs, Boy Scouts meetings, etc.
- A contact has been established with the Bethlehem Area School District wherein, as a part of their urban studies program, all seventh-grade students visit the watersheds. Through this program more than 1,000 school children receive first hand information on the Wild Creek project each year.
- Similar tours on a more professional level in the field of forestry and ecology are being conducted once or twice a year for the local colleges and university.

# CURRENT MANAGEMENT PRACTICES ON METROPOLITAN BOSTON'S MUNICIPAL WATERSHEDS

*by* BRUCE A. SPENCER, *Forester, Water Division, Metropolitan District Commission, Commonwealth of Massachusetts, Belchertown, Massachusetts.*

*ABSTRACT.* The Metropolitan District Commission is a state-municipal agency that directs an active management program to supply water, sewage, park, and some police needs for 32 towns and cities of the metropolitan Boston area. Four major aspects of the management program are described: watershed management, regulation and control of management activities, silvicultural practices, and wildlife management proposals.

THE METROPOLITAN District Commission (MDC) is the state-municipal agency directed to supply the water, sewage, park, and partial police needs for 32 cities and towns of metropolitan Boston. The Water Division of MDC has water rights to approximately 500 square miles of watershed from which it consumes 100 billion gallons of water per year. The principal watersheds in this system are the Quabbin and Ware River Watersheds, on which we manage 75,000 acres of land.

Historically this land had very limited management except for protection and the planting of open land to conifers. Eventually, the obvious responsibilities of ownership manifested themselves, and MDC initiated extensive watershed-management practices in 1960. The primary concern of this management is to maintain a healthy forest that is directly related to sustained yields of clean water.

## WATERSHED MANAGEMENT

In our region the forest is a major influence in the detainment and consumption of water between the time the land receives it as precipitation to the time it reaches the reservoir as streamflow. Evapotranspiration on our watershed is relatively constant regardless of rainfall, and consequently streamflows vary tremendously from dry to wet years. To increase water yields, our management efforts are concentrated on reducing the natural density (stocking) of the forest to lower the levels of evapotranspiration.

Therefore our efforts between 1970 and 1980 will be directed toward the following tasks:

- Commercial silvicultural treatments on 12,000 acres of forest, removing approximately 40 percent of the merchantable basal area or 2,600 board feet per acre.

- Thinning 3,000 acres of conifer plantations by cutting 15 to 20 percent of the basal area.
- Converting 500 acres of stagnated red pine plantations to fields of grass and herbaceous growth.
- Maintaining healthy wildlife populations to control the regrowth of premature undesirable regeneration.

I feel that the impact of this work on water yields is significant for our watershed. This significance is backed up by the following research studies.

The MDC, in co-operation with the University of Massachusetts, carried out several types of cuttings and treatments on a gaged watershed of 400 acres. The principal treatment was a timber sale employing various silvicultural cuttings ranging from single-tree selection to shelterwood on 200 acres. Noncommercial treatments involved deadening 40 acres of riparian overstory and 80 acres of riparian understory, plus heavily thinning 40 acres of pine plantations. These combined treatments increased water yields 12 to 22 percent for the first five years.

Research on the New York State Forest Preserve showed a decrease in water yields by 23 percent over a 35-year time span when no cutting took place on a gaged watershed. *(Eschner 1965)*. I am well acquainted with the forest conditions that produced both of these results and feel confident we can create forest conditions on our watersheds that will maintain a 10-percent increase in water yields over natural forest conditions.

The following are some of the main factors that will assist us in creating and maintaining the necessary forest conditions on most of the watershed.

1. Ownership of two-thirds of the watershed.
2. Average forest age of 55 years.
3. Practically all species and grades are merchantable to 8 inches dbh.
4. Moderate terrain that allows commercial logging on most of the watershed.
5. Large populations of deer and beaver, which control the normal forest regrowth following a harvest cutting through browsing and complete control of much of our riparian vegetation through beaver flowages.

The type of forest being produced from these influences is a healthy park-like forest of quality trees that will provide the source of a new forest when this becomes appropriate.

In the past 10 years, watershed-management operations treated 10,000 acres of forest, and should have yielded an additional 3.3 billion gallons of water, valued at $200,000, plus 33 million board feet of stumpage valued at $658,000. This decade (1970-1980) we will treat 12,000 acres and produce similar yields but of greater value. This increased water yield seems like a small contribution, but it is more economical and of higher quality than other additional sources of water.

## REGULATION AND CONTROL OF MANAGEMENT ACTIVITIES

### *Boundaries*

The maintenance of property boundaries is vital to our program and requires a constant care of property corners and lines to control activities from without and within.

### *Management Zones*

Delineation of management zones is necessary to recognize boundaries of areas that received different types of uses. A specific management policy is developed for each zone. The following six zones have been established and mapped.

| *Area use* | *Percent* |
|---|---|
| 1. Watershed management | 83.0 |
| 2. Esthetics | 6.0 |
| 3. Protection | 6.0 |
| 4. Administration | 0.5 |
| 5. Wildlife | 3.5 |
| 6. Recreation | 1.0 |

Each area requires specific silvicultural practices or protection to preserve the necessary environmental conditions. Basically, our silvicultural goals are to maintain and improve the health and quality of the forest; salvage defective, mature, and dead trees, especially unhealthy pine plantations; and prepare sites for the regeneration of native species.

### Records

A supplementary control function is an accurate record system designed to record all management activities on watershed lands. Several management blocks of similar size are delineated by natural and man-made boundaries. A single record book is used for each block that has an average of 16 compartments of 700 acres in size. For each compartment we have an 8½ x 11 USGS topographic map with a scale of 1,000 feet to the inch, on which to record and note all activities.

### Continuous Forest Inventory (C.F.I.)

Our present CFI program was adopted in 1960, with the establishment of 350 one-fifth acre sample plots. These plots were located by drawing a ½-mile grid on a USGS map of MDC lands. Under the CFI system, the plots are remeasured at 5-year intervals. Consequently, the forest is monitored over time to determine the effects of all influences imposed by man and nature. The growth, vigor, damage, mortality, quality, desirable silvicultural practices, etc. for each tree within the sample plots is determined in the field. These data are then processed by a computer program, which produces both plot and tree reports and forms the basis of our management plan.

### Planting

Although a minor aspect of our management program, approximately 15,000 white pine seedlings are planted each year. These are planted in forest openings made by recent harvest cuttings.

### Weeding

There are relatively few acres of forest in the seedling and sapling age class, consequently only a small amount of this type of work has or will be done. This work entails the mechanical cutting of gray birch and other weeds from pine and hardwood stands.

### Thinnings

With many thousands of acres of conifer plantations, there will be a continuing need for thinning. Some plantations have stagnated, and thinning is too late for them. When row thinning was carried out in these stands, the slight opening was soon filled with broken and bent trees.

Consequently, our precommercial thinning has been and will continue to be carried out in stands that have expressed dominance. In these stands the cull trees are brought to ground level and lopped. Stumps are cut low to facilitate commercial thinnings that follow.

Commercial thinnings have been removing one or two complete rows of every three to four rows. Several hundred acres have been thinned in this manner.

Natural hardwood stands have been thinned by local firewood dealers. Approximately 10 cords per acre is marked for removal, primarily black oak, birch,

and maple. One dollar per cord stumpage is generally the selling price. Many thousands of acres need this work, but only 40 to 50 acres per year have been thinned in this manner.

### *Harvesting*

The commercial harvesting operation has been and will continue to be the main silvicultural practice on the watershed. This silviculture has been concentrated primarily in mature and overmature pine, hemlock, and mixed hardwood forest composed chiefly of oak and maple. A commercial timber sale removes one-half of the merchantable volume from these stands, chiefly of dying, poor quality, hurricane-tipped, and diseased trees.

Various silvicultural methods are employed, ranging from single tree selection to group selection. The diverse nature of our forest, along with the requirements of logging, dictate these methods of silviculture.

Only a small percentage of our timber sales are designed to produce a new forest. Consequently, we are planning two to three harvest operations in all stands before a seed tree or final shelterwood cutting is made. Any premature forest regeneration is prevented mainly by our sizable deer herd.

The resulting residual stands consist of only one or two age classes. Practically all of our present forests originated prior to 1938. They were established by an MDC planting program, the 1938 hurricane, and private logging operations prior to MDC ownership.

The three main forest types and species combinations that will comprise most of our future forest will be red oak, white pine, and hemlock.

Potential adverse forest influences — other than man-caused fires — are chiefly wind, snow, and ice damage. The 1938 hurricane certainly pointed out the problems of growing white pine on exposed sites. Oak forests in these same areas suffered minor damage. Ice damage is also severe for pine at higher elevations, so that only 20 percent or less of the watershed should ever be in this type, and then only in certain locations.

Fire damage can be kept to a minimum by maintaining a good road network for access to practically all areas. Also, all logging slash will be lopped close to the ground to speed decomposition.

The esthetic appearance of all silvicultural operations is very important to us and to the public that visits the watershed lands. To create an esthetically pleasing harvest operation depends on both the forester's skill and the logger's skill. Factors considered in maintaining acceptable forest esthetics are the logging road layout, slash disposal, intensity of silviculture, and the careful treatment of stands adjacent to historical sites, reservoirs, administration areas, natural areas, brooks, and rivers.

Before a timber sale is marketed, the terms of the contract are fixed. The overall timber sale contract is much the same for all sales in order to regulate the operation and insure the fulfillment of all goals. There are some specifications that vary from sale to sale, such as time limit, seasons when logging will be permitted, road requirements, and equipment allowed.

All other restrictions are standard for all sales, including sanitary rules and regulations, method of slash disposal, expected workmanship, penalty clauses for breach of contract, and other restrictive measures to insure good harvesting practices.

Probably the most important ingredient for success of a timber sale is the logger's pride in workmanship. If he possesses this characteristic, then supervision by the forester is made easier and damage to the residual stand and

he land will be practically nonexistent. Foresters have attempted to reinforce his pride by evaluating the performance and workmanship of the completed timber sale. This evaluation sheet not only records good work, but also poor work, which will bear heavily on the selection of logging contractors for future jobs.

Although we carefully supervise logging operations to attain good results, we cannot control the weather, which has significant impact on the quality of a logger's work. Therefore some flexibility on our part as well as his part is absolutely necessary. Mud conditions can develop overnight from heavy rainfall; this is a good example of the necessity for flexibility. Mud is the enemy of the logger, landowner, and the land. We try to work around these conditions, which may come at any time of the year, but is usually a problem for only a month or two in the spring.

## WILDLIFE-MANAGEMENT PROPOSALS

The Quabbin Reservation is a wildlife sanctuary created by a legislative act. Since it consists of practically 50,000 acres in one contiguous block surrounding the Quabbin Reservoir, it is an extremely productive and effective sanctuary. Deer and beaver have been a major influence since the early 40s and 50s respectively. Their populations are enjoyed by the visiting public, and it behooves us to keep them as healthy as the forest since the public, the forest, and wildlife are essential to our watershed-management program.

The proposals for this decade are concerned with the following: timber-harvesting operations, power-line maintenance, creating and restoring open land, and plantation elimination. All these activities are aimed at enhancing our deer habitat.

### *Timber-Harvesting Operations*

Our harvesting operations are a continuous operation, so that any wildlife-management aspects applied along with these operations will be extremely important to the wildlife. A timber sale of any sort is beneficial to most wildlife, but by planning our sales carefully we can exert a much greater beneficial influence on the whole wildlife community than would normally be expected of a harvesting operation. There are many ways an operation can be improved for wildlife, and we work to incorporate some or all of these methods into our timber sales.

First, since our forest is on a plan of sustained yield, we will be theoretically harvesting timber forever, and therefore the impact of the sales will also be continuous. For deer management purposes we feel that these cuts should be distributed as evenly as possible throughout the watershed, and in this manner we can be sure that no one large tract of land is without food and cover.

Second, there are many marking guidelines that we will follow to increase the desirability of our wildlife habitat. Presently our marking is centered around cleaning up the forest by cutting the overmature, diseased, and defective trees. Elimination of these poorer trees creates hardwood sprouting and underbrush. Hemlock stands are treated very carefully so this valuable deer cover is not lost. Also, all large healthy oaks are left for the production of acorns. All these activities create and maintain food and cover for the whitetail deer.

Food and cover become very critical for the deer during winter months. We cannot create cover quickly, but large amounts of food are soon brought to ground level by the cutting of hardwoods. For this reason many of our hardwood sales are planned for winter months near areas of cover and little

food. Once spring arrives, all logging is curtailed, because of potential damage to the land and forest. This suspension of work is also beneficial to the thousands of newborn birds and animals, some common and some not so common. Therefore, as in the past, all logging will be done in the months July through March and, except for very rare cases, no logging will be done in the three spring months.

The logging techniques and methods used on the watershed are fairly well defined in our contract, but many things should be done which cannot be defined in the legal document. Presently, we are getting excellent cooperation from our loggers, and if this continues the wildlife will benefit in many ways. A good logger will cut many small suppressed trees to facilitate his operation, and these trees supply food from both their tops and sprouts. This also makes the harvesting operation much neater in appearance. We also require the logger to cut all his main skid roads, which not only produce more sprouting but creates both good trails and small openings for the animals to travel. Once the operation is completed, all log landings are planted with various species of plants beneficial to wildlife.

### *Right-of-Way Management Plan*

There are significant portions (500 acres) of power line right-of-ways, which provide important wildlife food and cover. Since the power company is continually maintaining their line, our work will coincide with theirs. By zoning certain areas of the line to specific treatments, we believe an important food supply may be protected and even propagated. The spraying crews try to leave blueberry bushes wherever possible, and by doing this have maintained some excellent patches. The determination of other plant species that are beneficial to wildlife will be continued, and in the next 10 years we hope to recognize all valuable forage and have all our power lines under intensive vegetation management practices.

### *Open Land*

In the next 10 years we are going to try to reclaim 50 acres of old abandoned field annually. Once these fields are cleared of pioneer weed species, they may be planted to various grasses or left to grow into low brush, depending on location and site characteristics. We hope that this program will supply not only deer browse but also the badly needed openings that our forest is lacking.

### *Elimination of Plantation*

The elimination of some of our poorer plantations is the last but certainly not the least project to be undertaken for our wildlife in the next 10 years. From a forester's and wildlife manager's point of view, these nonproductive plantations are wasteland, and we feel that a minimum of 50 acres per year should be eliminated. Because of heavy deer pressure, they will be maintained in native grasses and low herbaceous growth.

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I believe that the success of this program or any watershed-management program depends upon balancing the needs of both man and nature and then implementing the necessary silviculture practices to the highest possible degree.

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# CURRENT MANAGEMENT PRACTICES ON THE HARTFORD MUNICIPAL WATERSHED

*by* IRVING A. HART, *Superintendent, Water Bureau, Supply Division, The Metropolitan District, Hartford, Connecticut.*

*ABSTRACT.* This is an upland reservoir gravity-flow system serving 391,000 people, an average of 53 million gallons daily. Total watershed area is 133,664 acres, of which 30,424 are owned. Practically all ownership is forested. Employees number 56, including 11 uniformed patrolmen. The Superintendent is a professional forester, assisted by a second forester and a full time forestry crew of 3 men with modern equipment. Standing timber is marked and sold by bid under formal contract. Vegetative manipulation for improvement of water supply is minimal. Major distribution reservoirs are not open to the public, but an active recreation area is located on one reservoir not used for drinking water. Major trouble spots are the recreation area, control of trespass, pressure by special interests to influence usage, and those problems generally related to a bureaucracy supplying public services.

THE METROPOLITAN DISTRICT evolved from the Hartford Water Works, which was formed in 1852 and used the Connecticut River for its water source. Formal organization of the Metropolitan District occurred in 1930 under an Act passed by the Connecticut General Assembly, which provided for water and other services to towns in the vicinity of Hartford.

The main water supply is from Nepaug and Barkhamsted reservoirs. There are also four small older reservoirs in West Hartford. In addition to these water-supply reservoirs, there is the Compensating reservoir which was built to supply riparian right commitments and is now the site of an extensive recreation system. The Colebrook River reservoir was built by the Corps of Engineers as a multi-purpose reservoir and supplies the MDC with water in conjunction with its other uses. The gravity-flow system serves 391,000 people, and the average daily consumption in 1972 was 53 million gallons. The categories of use were 50 percent domestic, 26 percent industrial, 19 percent commercial, and 5 percent municipal.

## WATERSHED LANDS AND OPERATIONS

About 85 percent of our drainage area is forested. Of these 133,600 acres, the MDC owns 30,424, of which 5,121 are water surface and the remaining 25,303 are almost completely forested.

There are 56 people concerned with source-of-supply functions, including 11 uniformed and armed patrolmen. The superintendent in charge of reservoir lands is a professional forester, and another forester is in charge of the de-

tailed forestry work, including timber sales, supervision of a full-time three-man logging crew, and supplemental operations.

## FORESTRY PROGRAM

We are active in the production and sale of forest products. Although all cutting is done with stand improvement in mind as the primary consideration, actually most of it is more of a salvage nature. The cutting in young stands is minimal except for fuelwood and log-cabin poles — we would like to expand this part of our program. Large sales of standing timber over 50,000 board feet are marked and sold by formal contract to the highest bidder.

The logging crew normally is concerned with smaller operations and salvage work, resulting in sawlogs delivered to local mills at standard prices. They have modern equipment, including a skidder, hydraulic log loader, and heavy truck.

The 1972 gross income from the sale of forest products was $45,108. The sources were as follows: standing timber, 319,000 board feet sold for $5,420; sawlogs, 462,000 board feet sold for $28,000; log-cabin poles, 86,000 board feet sold for $4,481; and fuelwood (standing, wholesale, and retail), 848 cords sold for $6,526. Stumpage rates in this area have always been low, averaging a consistent $16 per thousand board feet for over 20 years. This is probably due to an abundance of timber and too few conversion facilities. However, a recent (August 1973) sale of average timber was made for $38 per thousand board feet and 9 bids were received.

There is no pulpwood market except for asphalt shingle material, which sells standing for 35¢ per ton and the fuelwood stumpage of $1.00 per cord.

## WATER-SUPPLY CONSIDERATIONS

The manipulation of vegetation for improving water yield is minimal, although we have that in mind in all our activities. Extensive harvesting of timber under the selection system of silviculture on a watershed equipped with a weir and continuous measuring device showed no detectible increase in the several years when the sales were made. We aim for a mixed hardwood-softwood stand of less than maximum density and attempt to reduce evapotranspiration along streambanks by cutting the large trees that have their feet in the water. We are still trying to maintain shorelines of coniferous trees, although the theory that it is important to keep hardwood leaves out of the water to improve quality is not critical, in our opinion.

We regard Barkhamsted Reservoir water as very good quality, but we have algae problems at Nepaug. Our water supply is sufficient to meet current needs, but additional supplies, probably from the Connecticut River, will be necessary by the year 2000. We are improving a 100-mile network of roads to facilitate control over our operations, and we find it vital for fire protection, trespass control, and timber harvesting.

Herbicides are not used in our forest management practices, but we use Amate X for control of shoreline and rights-of-way vegetation. However, where possible, we are trying to convert to mowable rights-of-way and to shoreline of conifers, laurel, and the sweet fern-bayberry type of ground cover. Ortho Diquat was successfully tried for aquatic weed control in one West Hartford reservoir.

## RECREATION

In general MDC lands in Connecticut adjacent to distribution reservoirs are not open to the public. This involves about half our acreage. Much of the

remainder is open to hunting and fishing, particularly in the less populated areas in Massachusetts. Camping is not allowed anywhere. Our patrol force tries to keep close control of all activities on our properties, including those activities that are sanctioned.

We maintain intensive recreation activities, including boat livery and bathing beaches on the Compensating Reservoir, which is not a drinking water supply reservoir. Less intensive recreation, swimming excluded, is allowed at the Colebrook River Reservoir, but is not under MDC jurisdiction. Although the problems involved with recreation are many, acute, and expensive, it is only in areas of intensive use that much deterioration of resources occurs.

## PROBLEM AREAS

Our problems are people-oriented, not resource-oriented; and we could be worse off than we are. The major problem is the recreation area and its attendant annoyances. The small fraction of the public that could charitably be described as ungrateful, unappreciative, and uncooperative contaminate the whole outlook. The recent Occupational Health and Safety Act (OSHA) requirements on capital facilities ran up our costs, and operating revenues are considerably less than our costs.

We have found it difficult to formulate a cohesive overall recreation plan to guide our future actions, and the problems get worse yearly. We tend to react instead of planning and acting. A recent evaluation of our organization by a management consulting firm mentions the need for clarification of the policy and approach to recreation and points out that its scope and propriety have never been established as a policy.

While the same might be said of the forest-management program, the problems are not acute and are of a nature reflecting the ambitions of the foresters versus the fact that management of the watershed forests is only a small part of the MDC water program. There is a general understanding about the objectives of the watershed-management program, but no formally written policy or plan with objectives. For 20 out of the last 25 years the problem was inability to get out of low gear, but recently progress has been made to the point where we are harvesting more than half of what we should yearly.

A related problem is the conflict between the need for more man-hours to be spent on forest management and the concern for liability and sanitation problems involving outside contractors on our land. At present the attitude is that the results in many cases do not justify the risk, and the solution has been to use our own more expensive employees to a greater extent.

Also, I sense a general lack of appreciation, both on the part of management and the general public, of the potential for improving the yield of forests by cutting, and of the related characteristics of forest products in that they are abundant, renewable, bio-degradable, and low energy-consuming in their manufacture. Although these facts are well spelled out in national policy, they seem to be easily forgotten when some exponent of a shallow special interest group writes to the editor.

It seems to me that the nub of our present problem lies in the conflict between the understanding by foresters that cutting signifies improvement, whereas others associate it with disaster. I prefer the consideration and establishment of policies that are definite and aggressive approaches to these matters rather than a defensive posture, with decisions being made without consulting those knowledgeable in the total national picture. This has been described

as the Age of No, and with the national climate of destructive criticism without plausible alternatives, plus the millions of instant ecologists waiting in the wings, one needs all the faith and optimism he can muster.

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# CURRENT MANAGEMENT PRACTICES ON THE PROVIDENCE MUNICIPAL WATERSHED

*by* HANS T. BERGEY, *Watershed Manager, Water Supply Board, City of Providence, Rhode Island.*

*ABSTRACT.* The water supplied by the City of Providence Water Supply Board is obtained from a 92.8-square-mile watershed on the north branch of the Pawtuxet River. The City owns 23.93 squares miles or about 25 percent of the drainage area. Surface water is collected in the main Scituate Reservoir and five tributary reservoirs, which have a total surface area of 7.13 square miles. The Providence Water Supply Board provides potable water to over half the population of Rhode Island in 11 cities and towns, representing an estimated 431,000 persons. The average daily consumption is 64,400,000 gallons per day. Management of departmental watershed and forest lands include forest culture and harvest practices; forest protection; and care of related facilities such as fire lanes, access roads, fences, turfed areas, and dams; and resolution of a myriad of associated people problems in an urbanizing environment.

THE WATER SUPPLIED by the City of Providence Water Supply Board is obtained from the 92.8-square-mile watershed on the north branch of the Pawtuxet River. The City of Providence owns and controls 23.93 square miles or about 25 percent of the drainage area. Surface water is collected in the main Scituate Reservoir (fig. 1) and five tributary reservoirs, which have a total surface area of 7.13 square miles.

The Providence Water Supply Board provides potable water to over one-half the population of Rhode Island in 11 cities and towns. The total population supplied is an estimated 431,000 persons. The average daily consumption is 64,400,000 gallons per day. The maximum daily use recorded was 109,000,000 gallons on 30 June, 1971.

Under the enabling act of 1915, the City of Providence was authorized to condemn land and establish a water supply for Providence and specific outlying areas. A total of 1,195 buildings, including dwellings, schools, churches, power plants, and six large cotton mills were condemned. Six villages and portions of two others were within the area to be flooded or on land condemned for marginal protection. The area condemned was sparsely settled, with a considerable portion in woodland, brushland, or pasture, and a relatively small area under cultivation *(Craig 1926)*.

Departmental lands marginal to the reservoirs total 11,000 acres and are covered by forest vegetation. The 68.87 square miles of watershed not owned by the Water Supply Board are esti-

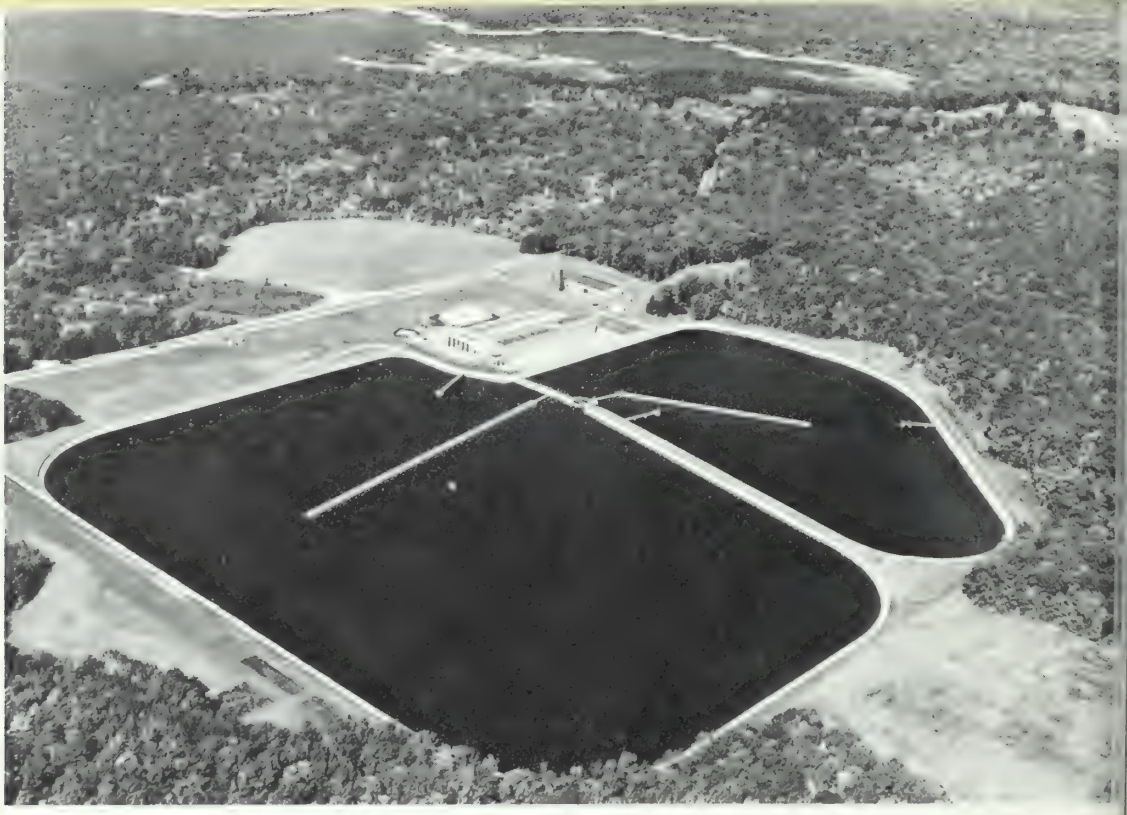


Figure 1.—Philip J. Holton Water Purification Works in Scituate, Rhode Island. Coagulation basins in foreground; portion of main Scituate Reservoir in background.

mated to be 10 percent cleared, 20 percent residentially developed, and 70 percent forested. Cleared land consists of agricultural, recreational, or idle acreage. Primary agricultural uses are pastureland and orchards. Residential and commercial developments are generally concentrated along state and town roads. Existing industry is light and has little effect on the water resources.

Lull *(1968)* described the forest region in which the watershed is located as white pine-hemlock-hardwood. Fires, hurricanes, and past cutting practices have had a major effect on present forest-stand composition. Extensive stands of mixed oak *(Quercus* sp.) of sprout origin are common on the well-drained and droughty sites. Swamps are prevalent and are characterized by red maple *(Acer rubrum)* and other wetland species.

Interesting aspects of managing the property are the past reminders of habitation such as stone walls, foundations, old cemetery plots, abandoned town roads, and unusual relics. Village and dwelling sites have influenced tree species found in woodland. For example, a significant forest stand of potentially valuable sugar maple *(Acer saccharum)* has resulted from seed dispersed by trees which at one time cast shade over a cotton mill and mill houses.

The Water Supply Board initiated a reforestation program in 1926, soon after construction of the Scituate Reservoir dam was completed. Extensive tree planting was accomplished between 1935 and 1943 when approximately 5,000,000 trees were produced in a nursery operated by the Department. Limited forest-culture work began in 1946 and continued till 1951, when the first professional forester was employed. The

watershed management program has increased progressively in scope to what now exists.

The present staff of the Department's Forestry Division consists of two professional foresters with job titles of watershed manager and forester, two security inspectors, and a work-force crew of 10 men headed by a foreman. The watershed manager is responsible to the chief engineer for all watershed-management programs. The forester supervises security personnel and woodland operations. The foreman reports directly to the watershed manager in the conduct of work activity on the watershed and parts of the distribution system.

Watershed-management programs can be described generally as follows:

- Forest management on departmental lands to include forest culture, timber harvest, and forest protection.
- Care of facilities on the watershed such as fire lanes, forest access roads, fences, turfed areas, and dams.
- Maintenance of aqueducts, covered reservoirs, rights-of-way, and grounds within the distribution system.
- Enforcement and security.
- Sampling and gaging of tributary streams and reservoirs; obtaining climatological data.
- Surveillance of the entire watershed to identify existing and potential threats to the quality of the raw water supply.
- Resolution of a myriad of associated people problems in an urbanizing environment.

## MANAGEMENT OF WATERSHED AND FORESTS

Management and administration of property owned by the Water Supply Board is facilitated by complete sets of records, plans, aerial photographs, and maps. Property lines and bounds are identified. Departmental lands are divided into compartments by a mapped grid system and the forest into working blocks by natural or man-made features. Statistical records of trees planted, wood products harvested, and management practices have been consistently maintained over the years. This information proved valuable in recent survey work conducted by Hadfield *(1972)* on *Fomes annosus* in forest plantations.

Boundary lines and bound locations are reviewed periodically. A system of painted tree blazes has been established to mark unfenced property lines. Forest access roads are identified on maps and in the field by a letter-number code. The letter corresponds to the block in which the road occurs. Blocks are designated by both proper names and letters.

Much of the forest-culture work centers on the more than 7,000,000 trees planted on departmental lands. In the 1950s, pruning of plantations was a major activity. Esthetics, fire control, and upgrading of tree quality were considered in giving priority to this type of work. Another reason for extensive pruning was to induce pulpwood operators to thin plantations. Today, delimbing presents no problem to woods operators who work with direct-drive chain saws.

After open fields and arable areas had been reforested, substantial acreages of upland hardwood were underplanted with various coniferous species. The species planted in greatest numbers was white pine *(Pinus strobus)*, which has competed successfully in the understory. Shading by overstory hardwoods minimized damage by the white-pine weevil *(Pissodes strobi)*. Over 500 acres of understory conifers have been released by girdling and killing overtopping hardwood of inferior quality. Overstory hardwood has also been removed by harvest cutting. This practice is ad-



Figure 2.—Loading pulpwood onto hauling truck in contractual thinning operation conducted on watershed property.

vocated if woods operators and markets are available.

In recent years reforestation has consisted of planting conifers in occasional open areas and on upland oak sites where conversion to conifers or diversity of species is desired. Native conifers, white pine, and hemlock *(Tsuga canadensis)* are preferred species in our planting plans. Experience has shown serious insect, disease, and other environmental problems with exotics and species planted out of their natural range. Hardwood species, including yellow poplar (*Liriodendron tulipifera*), black cherry *(Prunus serotina)*, and white ash *(Fraxinus americana)* have been planted in coniferous plantations that have incurred extensive mortality caused by the root-rotting fungus *Fomes annosus*.

Thinning of plantations is conducted on a contractual basis by private woods operators (fig. 2). A local pulpmill has provided a continuing market for material removed in intermediate harvest operations. Plantations are selectively marked for thinning by the forester. Pulpwood cutters pay a fixed rate per ton for pulpwood stumpage.

Sawlog harvest operations have been carried out on over one-tenth of the watershed property in the past 10 years. After stands are marked and volume determined, sawtimber sales are approved by the Water Supply Board, based on recommendations received from the watershed manager. Reliability, quality of work, and attention to watershed protection are criteria given weight over stumpage return in selection of woods operators. In addition to pulpwood and sawlogs, forest products such as posts, poles, piling, witchhazel brush, cedar for animal bedding, and fuelwood have been harvested from watershed property (fig. 3).

Esthetic improvement of forest land adjacent to roads, communities, and facilities such as Gainer Memorial Dam has been common practice. Development of scenic vistas overlooking portions of the reservoirs has enhanced the appeal of the property. Press photographers utilize open-vista sites as evidenced on a number of occasions in the local newspapers. Main and secondary highways passing through the watershed are jammed with sightseers on Sundays and holidays, particularly in the spring and fall.



Figure 3.—Transferring hardwood logs from forwarder to hauling truck in sawlog-harvest operation.

The thinning of coniferous plantations, initiated in 1946 and continued in greater measure since 1951, has brought about the spread of *Fomes annosus* root rot. When serious instances of tree mortality became apparent, a stump-treatment control program was undertaken. Present practice consists of application of borax in granular form to freshly cut stumps. Woods operators apply the borax immediately after felling trees. The stumpage rate paid by operators is adjusted to accommodate for the treatment.

Major forest-insect problems have been experienced with white-pine weevil, larch sawfly *(Pristiphora erichsonii)*, and gypsy moth *(Porthetria dispar.)*. An infestation of gypsy moth is presently spreading throughout watershed forests. The impact of the insect may be particularly severe in upland areas where damaging defoliation of planted and volunteer conifers will affect diversity in stand composition. The Department supported an aerial-spray program in 1973, which involved the application of carbaryl on a portion of the watershed.

The Department owns and operates a strategically placed fire tower for detection of forest fires. During the critical fire seasons, the tower is manned by a member of the forestry labor force. Radio communications are maintained with State fire towers, patrolmen, and Water Supply Board personnel. Security inspectors are equipped with fire-fighting pumpers on their pickup trucks; however, the Department depends primarily upon volunteer fire departments in the local towns for suppression of forest fires. Acreage burned over in recent years has been negligible despite forest-cover types that are characterized and sustained by frequent fires. A good record in fire control can be attributed to prompt detection and suppression, access, and good luck.

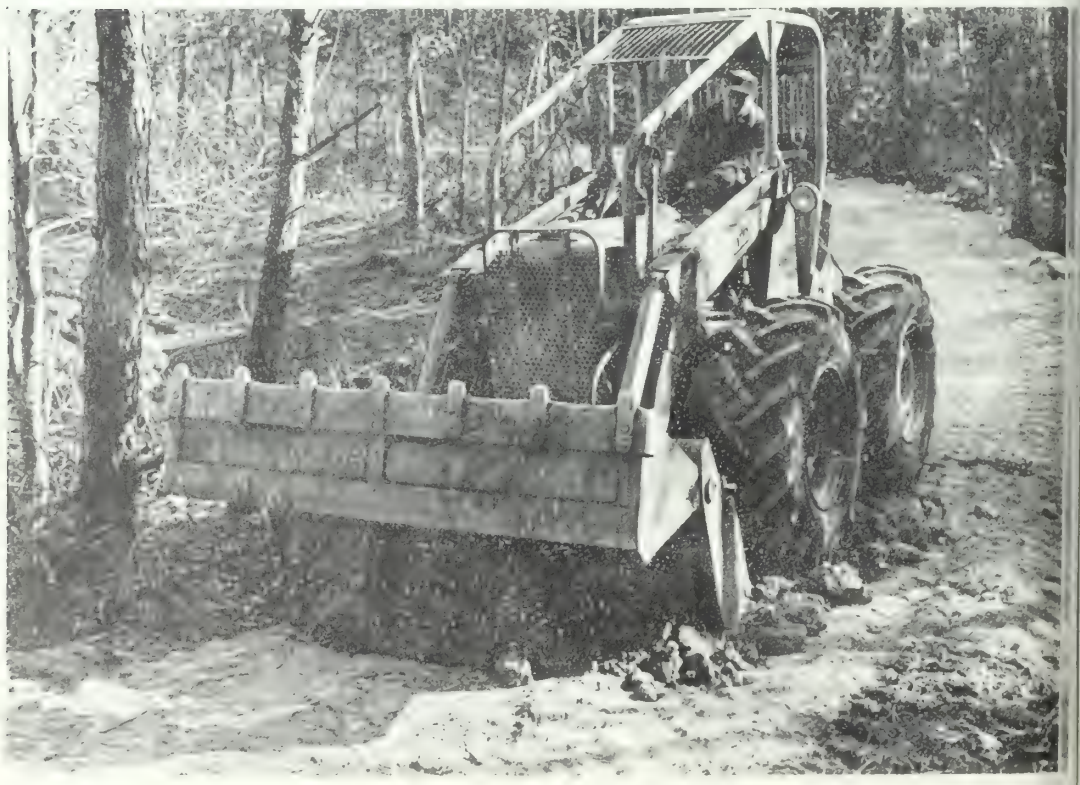
## CARE AND MAINTENANCE OF FACILITIES

Maintenance of watershed facilities such as forest access roads, fire lanes, fencing, dams, and grounds takes priority year-round. Access roads are being developed continually to permit reaching all regions of the watershed forest (fig. 4). Improvement work consists of rough grading, gravelling, and herbicidal brush control. The Department presently accounts for over 50 miles of forest-access roads, some of which are limited to travel by four-wheel-drive vehicles.

The use of herbicides has proved effective for controlling brush on forest-access roads, fire lanes, accessible shorelines, and adjacent to roadside fencing. The Department is limited to use of non-inhibited Ammate-X (ammonium sulfamate) in watershed areas. The non-selectivity of Ammate has created problems in its use; however, by exercising caution and good judgment, the herbicide has been employed in a variety of forest-culture and maintenance operations.

Turf management is an integral part of watershed management practice. Turfed areas at water-works structures, the main Gainer Dam, three underground distribution reservoir sites, and portions of the aqueduct system require varying degrees of turf maintenance. Much of the turfed area consists of steep embankments requiring specialized equipment to mow, fertilize, and tend. Fourteen acres of slope on the earthen Gainer Dam have presented a real challenge. The downstream turfed side of the dam faces to the south, and in all

Figure 4.—Improvement of forest access road by utility tractor.



seasons of the year the turf is exposed to extremes in temperature. During the droughty years of the mid 1960s, heavy insect infestation coupled with the drought resulted in almost complete loss of the turf cover on the steepest top slope. We worried through such questions as selection of grass species, means and time of application, and degree of erosion during the renovation period.

A problem worthy of mention in respect to turf management, particularly on sloped areas, is trespass by off-road vehicles. The motorized cycle is the primary offender; however, automobiles, snowmobiles, toboggans, and other conveyances have contributed their share of damaging trespass. The Department has found existing laws inadequate for prosecuting those who violate property in pursuit of recreation with off-road vehicles.

The Water Supply Board maintains a cemetery containing 427 burial lots in which remains were interred from cemeteries within and in close proximity to the flooded area. Occasional interments still occur, and a function of the Watershed Manager is to coordinate burials and maintain records.

## DISTRIBUTION SYSTEM

Within the Watershed Manager's realm of responsibility is grounds maintenance of certain portions of the distribution system, including aqueducts, underground reservoirs, pumping stations, and the main administration building. Horticultural, agronomic, and public-relations skills must be applied to a variety of circumstances that arise in the urban environment.

Aqueducts and pipelines provide avenues of travel for off-road vehicles, spreading points for poison ivy, collecting areas for discarded rubbish and litter, and extensions of many back yards. Wire fencing is little deterrent to the motorcyclist with a wire cutter in his back pocket. Boundary-line trees give shade to some back yards and are considered a threat to dwellings and personal safety to others. High shrubbery is desired as insulation from the neighborhood, but is denounced as a contributor to humidity and a harboring place for vermin.

## RECREATION POLICY

To safeguard its water supply, the Water Supply Board has established and enforced a policy of prohibiting recreational use in all reservoirs and on all marginal lands surrounding the reservoirs. The Department supports the 26 January, 1958 American Water Works Association "Statement of Policy on Recreational Use of Domestic Water Supply Reservoirs" *(AWWA 1958)*. Holton *(1967)* described the Department's current policy, which permits no recreational use on the terminal Scituate Reservoir. Recreational use, limited to boating and fishing, would be allowed on upstream reservoirs under proper safeguards and controls. The Water Supply Board feels that its water consumers should not be required to underwrite the cost of a recreation program. Collins *(1971)* provided a detailed review of literature describing problems associated with recreational use of public water supplies.

## ENFORCEMENT AND SECURITY

Enforcement activity has become a significant part of the watershed-management program. The encroachment of suburbia, and proximity of the watershed to the metropolitan center of the second most densely populated state in the Union, are important considerations.

The Providence Water Supply Board paid over $800,000 in property taxes to various cities and towns in its 1971-72 fiscal year. The Department depends upon these communities for strong sup-

port in protection of its vital resources and facilities.

Department security personnel call upon local police authorities for assistance when violations are detected, and formal apprehension or arrest are required. Permanent records are maintained on all violators. Weekly reports are submitted to the Chief Engineer on all violations of departmental property.

Experience has shown a low incidence of trespass when prompt and effective action is taken to prosecute violators. Within the past several years, it became necessary to outfit security personnel with uniforms and badges. Adverse attitude from violators is becoming common. Recorded acts of vandalism exceeded either fishing or swimming violations in 1971-72. Examples of vandalism include destruction of signs, gates, locks, fences, rustic stone walls, planted shrubs, turf, gate houses, pipeline structures, and windows of facilities.

## SAMPLING AND OBTAINING CLIMATOLOGICAL DATA

In addition to enforcement activity, security personnel are given the duty of gathering water samples for bacteriological and chemical analysis of watershed streams, tributary reservoirs, and the Pawtuxet River. Samples are collected daily from designated points throughout the distribution system. Elevations of the five upstream reservoirs are measured weekly.

The Water Supply Board has established five stations for the purpose of obtaining climatological data on the watershed. The stations are situated to provide optimum coverage of the drainage area. With the exception of the Gainer Dam station, part-time employees man the stations at their residences. Two additional stations are located at points off the watershed. Daily observations of precipitation, temperature, and weather conditions have been recorded since 1 November, 1915 at two of the watershed stations. The Rocky Hill Station has been operated by the same keeper for the past 53 years.

## SURVEILLANCE OF THE WATERSHED

During the decade of the 1960s, the platting of sizable acreages jumped significantly on the watershed as the urban sprawl reached into the reservoir town of Scituate. The Water Supply Board recognized the potential impact of unchecked development within the drainage basin and gave testimony indicating this concern at appropriate town meetings. The towns also noted the effects of increasing population and attendant problems. As a result of both environmental and economic considerations, planning boards imposed tighter regulations, and zoning ordinances were adopted. Residency in Scituate has enabled the Watershed Manager to become a member of the zoning board which presents an opportunity to monitor and have a voice in community development.

There is no formalized program for reviewing and policing existing septic systems on that portion of the watershed not owned by the Water Supply Board. The Department depends upon sampling of tributary streams, citizen complaints, and occasional checking of suspected problem areas by its personnel. The State Department of Health is the responsible agency for overall pollution control in sources of water supply. Despite prompt attention by the State Health Department when violations are reported, remedial work frequently proves to be only temporarily effective because of perennially poor drainage conditions. The best control is to recognize potential pollution sources and take necessary action before development

occurs. Recent passage of a State wetlands act, and adoption of restrictive regulations by the State Health Department in the design and construction of individual sewage-disposal systems, should provide greater protection in the future.

## WATERSHED MANAGER'S ROLE

The role of watershed manager is a challenging experience. He must supervise and manage personnel; work with colleagues in other professions; deal with politicians, unions, and ecology-minded citizens; cooperate with law-enforcement officers, public officials, fire fighters, and educators; appease adjacent property owners, neighborhood youngsters, and recreationists; and answer for a myriad of associated people concerns. In meeting these problems, it is often necessary to entrust the watershed's natural resources to the Great Caretaker above.

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# CURRENT MANAGEMENT PRACTICES ON PRIVATE MUNICIPAL WATERSHEDS

*by* JAMES F. HEAGY, *Forester, American Water Works Service Co., Inc., Camp Hill, Pennsylvania.*

*ABSTRACT.* Since 1954, sawtimber, pulpwood, and mine props have been harvested from 17 forested watersheds in Pennsylvania. Drainage from 15 areas flows into reservoirs used as sources of supply serving 14 communities. Potable water delivered from 8 of these reservoirs is not filtered. In no instance does the total acreage owned comprise the total drainage area of a reservoir. The harvesting and cultural practices used in the upland oak and bottomland hardwood types are emphasized. Other watershed programs discussed include recreational use, problem areas, and use of herbicides.

THE AMERICAN WATER Works Service Company, Inc., is a stock company operating water companies in 20 states, serving almost 5 million residents of 500 communities. All water companies are subsidiary utility companies, operating under regulatory processes. American Water Works Service Company, Inc., is a subsidiary of the parent company, having a general office in Philadelphia. In addition, there are eight division offices and three regional engineering offices strategically located throughout the system. Each division office has a president who is responsible for the operation of all water companies in his division. The engineering offices are staffed with mechanical, electrical, and civil engineers, draftsmen, estimators, and chemists. They are responsible for construction, purification, planning, and problems relating to delivering potable water to company customers. As forester for the company, I am responsible for management of all forested watersheds throughout the company system.

I will deal primarily with management practices used on watersheds located in all of the three major forest regions of Pennsylvania. Five in the oak-yellow poplar region contained 4,000 to 15,000 board feet per acre. In the white pine-hemlock-hardwood region, volume per acre on ten watersheds ranged from 5,000 to 19,000 board feet. In the northern hardwood region volume per acre varied from 4,000 to 12,000 board feet per acre in two watersheds.

Drainage from all watersheds flows into streams feeding reservoirs. In no instance does the acreage owned comprise the total drainage area to a reservoir. Potable water delivered from eight reservoirs is not filtered.

Watershed areas vary in size from 50 to 2,500 acres. All except one are 100 percent forested. Populations served by

companies owning these watersheds vary from 1,350 to 81,000. The yearly amount of water delivered by the smallest company is 16 million gallons as compared to 3 billion gallons by the largest company. Residential use of water varies from a low of 16 percent to a high of 85 percent.

## FORESTRY PROGRAMS

Before 1954, the noise of a chainsaw was never heard in these 60- to 150-year-old stands. Since then sawtimber has been harvested from all 17 watersheds, pulpwood from 5, and mine props from 1. Single and group-selection regeneration methods have been used in harvesting timber along streambanks, on steep slopes above reservoirs, and in two uneven-aged stands.

Clearcutting was used in two situations. A 14-acre island in a stream channel in the white pine-hemlock-hardwood region was clearcut. Seven years after cutting, yellow-poplar, ash, soft maple, and advanced reproduction of white pine dominated the new stand. Clearcut strips 60 feet wide were made on 50 acres of an upland oak stand badly butt-scarred by repeated past fires. After ten years, dominant reproduction is a mixture of oak stump coppice, seedlings, and seedling sprouts.

The shelterwood system was applied in making sawtimber cuts in the bottomland hardwoods type. In these high-volume stands, oak reproduction was sparce or nonexistent. On two sites, weeding was necessary for red and black oak to become established after shelter-

Figure 1.—Group selection cutting on the Warren Water Company Watershed in Warren, Pennsylvania.



wood cuts 12 years apart. On a third site, oak has not become a component of the reproduction 10 years after a shelterwood cut removed 50 percent of stand volume. When a heavy invasion of brush is finally controlled by herbiciding, a second cut will be made. Predominant composition of the new stand will probably be yellow-poplar, ash, and soft maple rather than red and white oak.

Ten years ago, improvement and thinning cuts were made in three upland oak stands. Larger scattered red, black, and scarlet oak trees of poor form and quality were harvested as low-grade sawtimber. Pole-size trees were sold as pulpwood at two locations and as mine props in the third location. Income from these sales paid for the expense of marking and supervision of logging operations.

Thinning and removing scattered old-growth trees in two northern hardwood stands yielded sales of pulpwood and sawtimber. Sodium arsenite was used as a debarking agent for pulpwood sold from 1963 to 1968. After 1968, mechanical debarkers were installed at the pulpmill, eliminating the need for delivering peeled wood. During 1971 and 1972, pulpwood was skidded and hauled in tree length to a centralized debarking and chipping operation.

In 1955 in an area lacking a pulpwood market, a white pine-scotch pine planting was thinned, and crop trees pruned to a height of 17 feet. Carrying charges for this type of operation were too high to justify continued application of this procedure. Row thinning in a 40-year-old white pine-red pine planting in an area having a pulpwood market was financially feasible.

Since prices paid for pulpwood stumpage are standard for any given region, the operator was selected for harvesting pulpwood rather than using bid procedure. All sawtimber has been sold on a sealed-bid basis. To date, 7 million board feet of sawtimber and 14,000 standard cords of pulpwood have been harvested from 8,300 operable acres on 17 watersheds.

## WATERSHED PROGRAMS

Silt-collecting dams upstream from two Uniontown Water Company reservoirs have been cleaned. In certain areas, truck and skidroads used in logging were fertilized and seeded with a mixture of orchard grass, domestic rye grass, red top, and Kentucky 31 fescue. The banks of a breached impoundment were also seeded to the above mixture. After brush and seedling tree growth were eliminated with 2,4,5-T, one reservoir bank was seeded with crown vetch.

To reduce interception of snowfall, 40-foot-wide strips were cut through a small pole-size hemlock understory on a steep west-facing slope. At the foot of the slope, springs erupt that supply a small reservoir. Since disturbance of the litter layer could have resulted in turbidity reaching the springs, all felled trees were left lying on the ground. I have left the large pole-size soft maple overstory intact.

During and after logging operations, I have eliminated cull and undesirable components not designated for cutting, using the frill method. Frilling is done with a 2-pound marking ax. A 2-quart oil can is used to apply the herbicide. Brush and sapling growth on certain reservoir banks have been controlled with the use of a brush-killer in a water solution applied with a backpack mist-blower. Brush in pipeline rights-of-way and a dense beech understory in a northern hardwood stand have been controlled in the same manner. Potamogeton pond weeds were controlled in one reservoir by using a granular type 2,4-D applied in early spring.

## RECREATION AND PUBLIC RELATIONS

Wooded areas adjacent to reservoirs that supply unfiltered water are posted with NO-TRESPASSING signs. All other forest holdings are open to the public for hunting, hiking, snowmobiling, and fishing. On company-owned property in northwestern Pennsylvania, the highway department has established a roadside rest area, maintaining a spring-fed water supply, picnic tables, and toilet facilities.

Near Muncie, Indiana, recreational activities on a company-owned reservoir site are operated and controlled by the city. Fishing, house-boats, swimming, and water skiing are permitted on different parts of the reservoir.

Local managers arrange tours of water-company facilities for school groups, usually of junior high age. These same groups have been shown logging operations adjacent to reservoirs supplying unfiltered water. A talk entitled "Watersheds — Our Source of Supply" illustrated with colored slides, has been presented to local service clubs. In both instances, the main objective is to prove that controlled logging operations on a watershed and a potable water supply from that watershed are compatible.

## PROBLEM AREAS

Any disturbance of the forest floor due to logging and the establishment of skid and truck roads can result in turbidity reaching stream channels and reservoirs. On steep terrain, particularly above reservoirs, skidroads can be built on the level, and timber can be winched to these roads rather than running logging equipment up and down the slopes. Excessive turbidity entered a stream on one watershed during and after logging operations because of incorrect location of a bridge crossing in a draw. But I am thoroughly convinced that any regeneration system can be used in harvesting timber on a watershed, if logging operations are properly planned and controlled.

Some of the watersheds are located in areas populated with a large deer herd. A major task every spring is the removal of dead deer carcasses from streams and reservoirs.

Indiscriminate dumping is a universal problem. Watershed land along public roads, even though heavily posted, is subjected to this abuse.

Arson on one watershed was finally stopped with the arrest and conviction of offenders by Game Commission personnel.

When urban development started on one watershed, turbidity entered a stream feeding three contiguous reservoirs and supplying unfiltered water. To circumvent the problem, the upstream reservoir is now used as a sedimentation basin. The surface supply had been augmented with a well supply. Future development of the well supply will result in the abandonment of the reservoirs as a source of supply.

Silvicultural treatment may have to be changed on watersheds when mineral rights are owned by a second party. The group-selection method was being applied in an uneven-aged mixed hardwood stand. When rigs started to drill oil wells on 450-foot centers, all timber had to be hurriedly removed. This was necessary to keep ahead of bulldozers leveling 50-foot strips through the forest. Turbidity from all cleared areas had been controlled by the well drillers.

## FUTURE MANAGEMENT

Since the drainage area of all these 17 watersheds constitutes only 2 to 50 percent of the total drainage area to a reservoir, any effect management practices would have on water quantity would probably be negligible. Maintenance of water quality and silvicul-

tural practices have been the primary factors considered. In the future, these same objectives will be emphasized.

On two uneven-aged high-density mixed-hardwood stands, reproduction was inadequate 8 years after removing 40 percent of the board-foot volume. Block cutting was then initiated on north-facing slopes, removing an additional 25 percent of the volume. This procedure will be continued at 5- to 10-year intervals, using a wait-and-see policy for the final regeneration cut. South-facing slopes are predominantly oak. Some oak reproduction is present in openings created by the removal of scattered older trees in the original cut. Hopefully a two-cut shelterwood system can be applied to regenerate these slopes.

Openings on the better sites are often invaded with sassafras, black locust, black gum, grape vines, and various shrubs. Cleaning will probably be required to assure the successful establishment of preferred species.

Hundreds of excellent research publications are available that give the watershed manager insight into the various facets of watershed management — evapotranspiration, interception, the forest floor, albedo, etc. Research has shown that cutting can increase water yield. Watersheds maintained for runoff supplying domestic and industrial use can and should be used for other purposes. They are not sacred groves from which recreation or economic use has to be excluded.

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# CURRENT MANAGEMENT PRACTICES ON NATIONAL FOREST WATERSHEDS: WHITE MOUNTAIN NATIONAL FOREST

*by* GORDON STUART *and* WILLIAM M. ALDEN, *respectively Watershed specialist, White Mountain National Forest, U.S. Forest Service, Laconia, New Hampshire, and Timber Management Assistant, Androscoggin Ranger District, White Mountain National Forest, Gorham, New Hampshire.*

*ABSTRACT.* Municipal water supply is one use of National Forest land. The Berlin, New Hampshire, municipal supply is an example of current management practices on the White Mountain National Forest. This is part of the Kilkenny Management Unit, which will be the first area to be completed under the current planning program to develop a fully integrated management unit for obtaining a good balance of resource use as related to land capability and resource demands. The Berlin supply has been and will continue to be managed for water, timber, wildlife, and recreation. Recreation use – primarily hunting, fishing, and off-road vehicle use – is not generally restricted. No campground development is planned, but hiking use is expected to increase. The timber-management program is designed to improve wildlife habitat and provide additional water yield. Protecting water quality is the primary concern.

THERE ARE 20 MUNICIPAL watersheds on the White Mountain National Forest. These vary in size of drainage, amount of public land involved, and type of installation. In most of them, daily stream flows are relied on to provide water. Installations range from only an intake to a small instream reservoir. Treatment is generally limited to chlorination; therefore there is special concern for any type of land use that may increase suspended sediments.

Land use on municipal watersheds has developed over many years. Hiking, camping, and hunting were established public uses of land before many municipal supplies were organized. We have copies of some of the early land-use restrictions on municipal watersheds. These, dating from 1915, seem to indicate that many activities were accepted. Such critical items as sewage disposal were restricted only where it would cause "defilement" of streams.

When these lands were purchased for National Forest purposes, most municipal watersheds and the land use on them were already established. Through the years, many agreements have been reached between municipal managers and the Forest Service on management activities. In most cases, established restrictions on watersheds have not changed. However, New Hampshire is requiring all surface supplies to provide full treatment in the future. This may have some influence on the future need for restrictions.

National Forest land use on the Berlin, New Hampshire, municipal watershed is presented here as an example of our current management practices (fig. 1). This watershed is in the Kilkenny Management Unit, the first unit to be completed under our current planning program. Reference is made to the Kilkenny Unit because our management practices are based on the resource zones of this entire block of National Forest land.

## BERLIN MUNICIPAL WATERSHED

The Berlin Municipal Watershed (fig. 1) is located in the headwaters of the upper Ammonoosuc drainage. National Forest land totals 12,150 acres of the 15,800-acre drainage. The upper portion of the drainage is owned by the Brown Paper Company. Elevations range from 1,500 feet to 3,890 feet, and the drainage is about 95 percent forested. The other 5 percent is a large alder swamp, which is located along the main stream channel.

The Ammonoosuc intake provides two-thirds of the water used by the 16,000 people served, approximately 2 million gallons per day. Berlin has two other sources of water on privately owned land east of the Androscoggin River.

## MANAGEMENT PROGRAM

The Kilkenny Management Plan provides the 10-year action program for the entire unit. Details of what, when, and how management activities are to be conducted are based on resource inventories. Functional activities have been coordinated by the planning process to provide a good balance of resource use as related to land capability and resource potentials. Within the unit there are several distinct resource zones. Therefore the unit has been divided into sub-areas and management objectives have been established for each sub-area.

The Berlin municipal watershed is located in portions of three sub-areas. This watershed has been and will continue to be managed for timber, wildlife, recreation, and water resources. While maintaining water quality for municipal use is the overriding concern, we have utilized the timber-management program to benefit directly the wildlife and water resources.

### *Sub-Area 1*

The lower slopes and streamside zones inside the loop road (FR15, Fig. 1) contain a major winter deer yard and a variety of wildlife habitats. The deer yard has been intensely managed for a number of years to maintain adequate softwood cover and optimize available winter browse. During the winter months, 100 to 200 deer utilize the yard. Logging is scheduled during periods of snow cover to provide additional browse during the critical winter period. Winter logging also minimizes soil disturbance on the wet soils in this sub-area. Current inventory data indicates that 40 acres can be regenerated annually on the 3,670 acres of this sub-area within the municipal watershed. Clearcuttings are the most common type of regeneration method.

Recreation use is primarily hunting and fishing. There is an active stocking program in the intake reservoir above Godfrey Dam. Native trout are relied on to provide the stream fishing in the remainder of the watershed. Off-road vehicle use is increasing, and there is growing concern about snowmobile use in the deer yard. At present, there is an unofficial closure on snowmobiling inside the loop road. Swimming is not allowed in the reservoir.

Figure 1.—The Berlin Municipal Watershed on the White Mountain Forest.

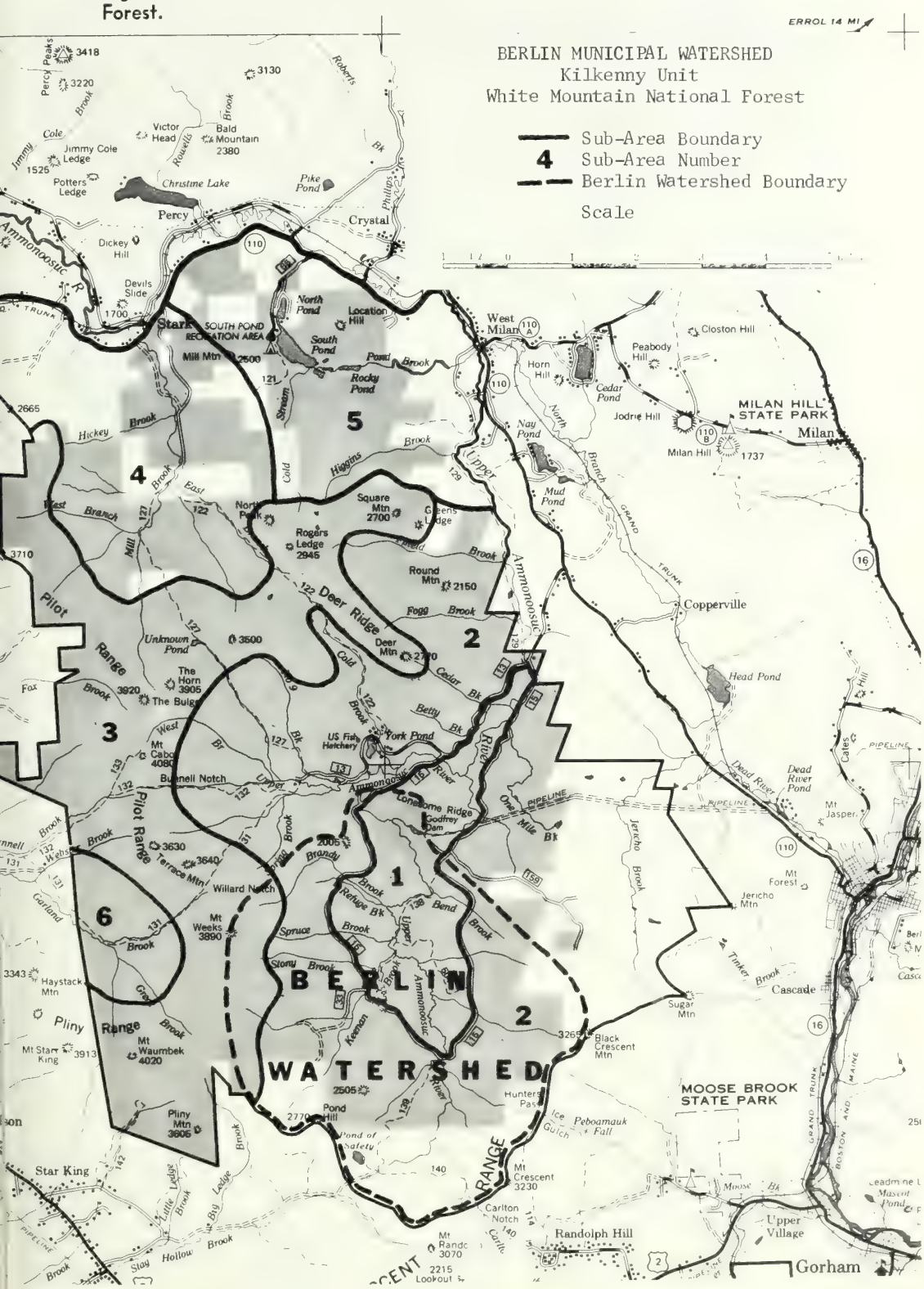




Figure 2.—Cutting units in sub-areas 1 and 2 are on either side of the intake reservoir. The loop road is in the foreground. Sub-area 3 is on the upper slopes in the background.

***Sub-Area 2***

The middle slopes above the loop road are primarily commercial forest land. Timber-harvesting activity has been scheduled to achieve specific purposes such as improvement of age-class distribution, stand quality, and wildlife habitat (fig. 2). Current inventory data indicate that 60 acres can be regenerated annually in the 6,500 acres of this sub-area that are within the municipal watershed.

Timber stands in sub-area 1 and 2 generally do not qualify for thinning cuts because of quality and age-class distribution.

Hunting use is heavy all along the loop road. Camping has been allowed near the road during the hunting season and will be permitted to continue at designated sites away from streams. Snowmobiling is increasing along the loop road, and there are plans for extensive snowmobile networks in this sub-area.

***Sub-Area 3***

The upper slopes above the 2,500+ foot contour will be managed as a back-country area, primarily for dispersed recreation. For the entire Kilkenny Unit, sub-area 3 totals 17,500 acres. Only 2,000 acres are in the Berlin municipal watershed.

Presently, there is little hiking as compared to other areas on the Forest, and there are no developed camping sites. Through the planning process, we will take the opportunity to preplan for the anticipated increase in hiking use. Camping will be restricted to designated areas, and toilet facilities and tent platforms will be provided.

## SPECIAL RESTRICTIONS

There are many coordinating requirements on National Forest land uses, which have been established to protect water quality. Furthermore, it is National Forest policy to meet state water-

quality standards and the restrictions on class-A municipal drainages. Therefore we do not have a separate list of forestwide restrictions for municipal watersheds. Municipal use is taken into account in management plans.

### IMPACT ON WATER RESOURCE

The key item in any type of land use on a municipal watershed is its impact on the water resource.

Research results have established that clearcuttings will increase water yields during summer low-flow periods *(Lull 1967, Hornbeck 1970)*. By applying research results to the planned timber-management program on the municipal watershed, we estimate that flows can be increased 700,000 gallons per day during the summer *(Douglass 1972)*. This increase will be dispersed over the watershed, due to the scattered locations of the cutting units, and the increase may not be easily noticed at the reservoir. However, there is no doubt that increases in water yield occur below clearcut units.

Impacts on water quality are more varied, and the management key is to control use so that any adverse effects can be corrected before they reach significant levels. The control of suspended sediments is a major concern in any type of activity that involves the exposure of mineral soil — such as temporary road construction for timber harvesting. However, we make use of research findings to protect against erosion and sedimentation of streams. Such items as providing filter strips between roads and streams, and stabilizing roads after logging, are forestwide requirements.

Changes in water chemistry due to land use is another concern. As has been reported by research, nitrate levels do increase in the streamflow from clearcut units *(Pierce et al 1972)*. There are three key aspects of this nitrate increase that pertain to municipal watersheds. First, the increased levels of nitrate that have been monitored in normal clearcuttings or regeneration cuts seldom exceeds 20 mg/1. The U. S. Public Health Service standard for drinking water is 45 mg/1. Second, this standard is placed on water quality at the intake. Finally, the increase has been found only in the White Mountain area of Maine and New Hampshire.

We have checked nitrate levels starting on the 10 to 20 acres of the drainages where the increase is most noticeable, and we have sampled downstream. Nitrate levels decrease rapidly below the clearcut unit and return to normal on drainages larger than 1,000 acres. Therefore we believe that the established Forest requirements of clearcutting less than 25 percent of a 1,000-acre drainage during a 10-year period and keeping cutting units small and dispersed are adequate for controling adverse impacts.

There has been some question about managing the deer yard and whether concentrations of deer would increase bacteria levels. We have begun to collect some data on bacteria levels. Though our data are too limited for firm conclusions, it appears that during the winter most waste matter is frozen in the snowpack. In the spring melt, there is a large volume of water for dilution, and bacteria levels remain low. During the summer and fall low-flow periods, bacteria levels increase. Results to date do not indicate any relationship between the deer yard and bacteria levels. Total coliform has exceeded the state standard once out of 16 samples and this was above the deer yard. The main point is that the wildlife habitats of sub-area 1 will attract migrating birds, beaver, deer, etc. even if unmanaged. By improving the browse we are maintaining the herd in a more healthy condition.

Increased backcountry hiking can lead to waste-disposal problems. The mountain ridge lines of sub-area 3 are generally areas of shallow or rocky soils. Through proper planning, any future campsites will be located in suitable areas. However, we have had waste-disposal problems at other backcountry sites on the Forest. Our monitoring has indicated that, when these problems occur, they are primarily a local health hazard in the camping area. We have not found any significant downstream pollution from backcountry use. Because of the health hazard, the Forest requirement is that there will be no contamination of surface waters by waste-disposal installations.

There are two other aspects of water quality. First, the main stream is highly colored from natural causes. Color levels are about double the state standard even above the main swamp in sub-area 1. Second, there are naturally-occurring areas of streambank erosion. Because of location, it is unlikely that they have any effect on water quality at the intake, but stream turbidities are increased by the bank erosion that occurs during storms.

## CONCLUSION

The National Forest management program on the Berlin watershed has been cited as an example of current land-use practices. However, considering management activities on all our municipal watersheds, it has been our experience that properly planned and controlled land uses can provide many goods and services for the public and not significantly affect water quality. We have been conducting an intensive water-quality monitoring program on all types of National Forest activities for several years. Our monitoring results substantiate the fact that many land uses are compatible with municipal watershed management.

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# THE CONSULTANT'S ROLE IN MUNICIPAL WATERSHED MANAGEMENT

*by* CURTIS H. BAUER, *Consulting Forester, Jamestown, New York.*

*ABSTRACT.* Consulting forestry firms are in business throughout the Northeast. Their activities include formulation of watershed-management policy and objectives; financing forestry services; management plans; maps; boundaries; timber sales; timber harvesting; logging control and supervision; watershed protection; aesthetics; and public relations. Consultants can manage most forest watersheds in a suitable fashion to satisfy municipal policies and objectives.

I BASE MY REMARKS upon experience gained in managing two small watershed forests in western New York State and 19 years of experience as a consulting forester.

Those of you who are not acquainted with consulting forestry might well ask: What is a consulting forester? His formal training is similar to that of other foresters. Most consultants have a bachelor of science degree in forestry, and many have advanced degrees. Consultants, as do other foresters, frequently avail themselves of short courses offered by the various educational institutions. Consultants generally have gained experience in forestry through work with public agencies, industry, research, or educational institutions before venturing into this business.

A consulting forestry firm may be a single forester, or it may have a staff consisting of professionals with a number of specialized skills. The consultant is a businessman. Services rendered are charged to the client on a fee or contingency basis. The cost of services varies considerably from one part of the county to another, the range generally being between $50 and $125 per day plus expenses. Consultants usually have a contract with a client for a specific time period, covering all aspects of the services to be rendered and the remuneration to be received.

Many consultants belong to the Association of Consulting Foresters (ACF), which has headquarters at Wake, Virginia. A larger organization, the Society of American Foresters, to which most foresters belong, regardless of their type of professional forestry employment, has adopted a strict code of ethics, to which members of the Association of Consulting Foresters subscribe. The Association maintains a membership directory. Those in need of consulting forestry services can obtain the names and addresses of consultants by directing inquiries to the ACF headquarters.

## WESTFIELD WATERSHED PROPERTY

The Westfield property is situated in Westfield and Chautauqua, Chautauqua County, New York. The Village of Westfield owns 1,067 acres in the Chautauqua Creek watershed, which comprises approximately 23,000 acres. Steep slopes characterize the Westfield land holdings.

Parts of the Westfield property are poorly drained, and it contains some small swamps. There is a lack of a flood plain, and many V-shaped valleys indicate that stream-incising is the prevalent geologic process. The entire Chautauqua Creek Watershed is geologically characterized as youthful.

The bedrock geology has been described by Tesmer *(1963)*. The bedrock is Upper Devonian, consisting of the Ellicott and Dexteville members of the Chadakoin Formations, about 250 feet thick. The Northeast, Westfield, Shumla, and Leona members, about 680 feet thick, make up the Canadaway Formation. Superficial deposits described by Muller *(1963)* within the Village property are basically ground moraine.

The property is covered mostly by deciduous forests. Sugar maple is the predominant tree species; it is associated with beech, black cherry, white ash, yellow-poplar, red oak, hemlock, and other tree species. Some stands contain large overmature trees; others are of pole size. In 1962 the forest contained many large cull trees, and most of the stands were overstocked.

There are two water intakes in Chautauqua Creek. The Minton Reservoir has about 10 surface acres. Approximately 1,000,000 gallons per day are used for 47 weeks of the year, and during the food-processing season about 2,000,000 gallons per day are used. The average annual precipitation is 40 inches.

## ORGANIZATION

The Village of Westfield Mayor appoints and the Village Board of Trustees acts to approve members appointed to the Board of Public Utilities (BPU). The BPU, consisting of a chairman and four members, all unsalaried, govern both the water department and the electric department. There is a superintendent for each department. The forester works directly under the BPU and in conjunction with the superintendent of the water department.

## POLICY AND OBJECTIVES

It is necessary to establish a policy and set objectives for the management of a forest watershed. Too many municipalities that own watershed forests have no watershed policy. Policy formation and many management decisions are often promulgated by a board of public utilities or similar body that lacks the understanding and knowledge to fashion watershed policy or to set watershed objectives. Some BPU members are amazed to learn that the trees on their watershed are competing with their customers for the same water.

Watershed policy formation can be a joint effort between the consultant and the BPU members. Before meaningful policy can be developed and objectives established, it is often necessary for BPU members to learn about the existing natural resources and the relationships among plants, soil, and water. The consultant can provide much of the technical background necessary to develop the policy and establish goals.

The Village of Westfield Board of Public Utilities adopted a watershed policy to increase streamflow in the creek where the intakes are located and above the reservoir; to permit little or no water pollution from erosion; to maintain a vigorous and healthy forest to maintain an esthetically pleasing

forest, particularly along the main watercourse and roads; to purchase additional property to fill out and enlarge the watershed holdings; and to carry out the policy and objectives as much as possible within the limits of income produced from the forest.

### COMPREHENSIVE INVENTORY

Before developing a watershed management plan it is necessary to have an inventory of the property. Good property maps are frequently lacking. It is often necessary to locate deeds that describe the property and work out boundary descriptions from legal records. Tract maps, county maps, survey notes and sketches, tax maps, USGS quadrangles, and aerial photographs of the areas in which the properties are located are most helpful in developing maps.

The inventory on the Westfield watershed included topographic data, soils information, location of watercourses, all existing roads, location of water intakes, pipelines, rights of way, buildings, the reservoir, boundary references, and other physical features. Considerable information about the vegetation was gathered. Data about the species, size classes, density, health, vigor, and volume of the timber were collected. This information was related to maps and tables and later incorporated into a watershed management plan.

### WATERSHED-MANAGEMENT PLAN

The plan becomes the working document to guide all management decisions. The plan blends the policy and objectives with the collected inventory information. The Westfield plan was developed for a 10-year period. A plan must not be rigid, but fluid enough to incorporate changes. The Westfield plan contains timber-harvesting schedules, timber-stand improvement schedules, timetable for road construction, erosion-control recommendations, tree-planting schemes, boundary-line maintenance program, logging standards, land-acquisition goals, and a sub-plan on how all of these objectives can be achieved within the funds available.

Execution of the Westfield plan happens only after approval by the BPU. As an example, before a road is constructed, approval must be given by the BPU. Approval is based on the cost, availability of funds, and how the road fits the overall plan. This procedure enables the BPU to participate in the management decisions and to keep control of the forester's activities.

### BOUNDARIES

Seldom are the boundaries of forest properties in good condition. It is necessary to locate property boundaries before certain forest management practices can be conducted. Frequently the old boundary lines and property corners can be located. Sometimes certain lines must be surveyed. Many consulting foresters are licensed surveyors.

On the Westfield watershed, the old lines and corners were located, blazed, and painted. Boundary signs were posted along the lines and at the corners. Maintenance of all the boundaries are on a 10-year schedule.

### TIMBER MANAGEMENT

Timber harvesting is viewed as a method of manipulating the vegetation. Considerable research has been done on increasing water yields through timber harvesting. Increased water yield is a policy objective of the Westfield BPU. Timber harvesting not only increases water yields but results in timber sales, which in turn provides income.

During the first 10-year plan, it was

decided to remove timber from about 500 acres. Since 1963, ten timber sales have been made on forest compartments ranging in size from 30 to 80 acres, including altogether 421 acres.

One objective of the timber-harvesting program has been to remove the large overmature trees, which consume much water. All cull trees have been cut or deadened in each sale area. Selective cuttings have been in stands overstocked with sawlog-size trees.

There is considerable variability in age classes throughout the watershed forest. None of the stands are ready for reproduction cutting. It seems desirable to reproduce these hardwood forests at a later date by the shelterwood or group-selection methods. The possibilities of timing the last stages of a shelterwood cutting on certain compartments at a time when high water yields from the watershed are needed, appears to have intriguing prospects.

Sawtimber sales are made by marking trees to be harvested. A prospectus is developed, outlining the conditions of the proposed sale and listing the marked timber by species, number of trees, and volume. A map of the sale area is prepared. The logging conditions are specified. The prospectus is sent to area timber buyers, and sealed bids are required. A contract is executed between the buyer and the seller. Payment for the timber is made when the contract is executed.

To control the logging, we require the purchaser to post a bond. The bond money can be used to correct logging damages. The seller reserves the right to stop all logging when weather conditions or poor logging practices are such that damages become unacceptable. Other restrictions are placed in the contract to protect the watershed. The job is inspected periodically to insure that the contract specifications are met.

As the logging progresses and at the end of timber cutting, truck roads are ditched, waterbars are placed where needed over skid trails and truck roads, culverts are cleaned, and wheel ruts are filled. Log landings and roads subject to erosion are seeded and mulched.

Overstocked pole stands have been thinned by deadening undesirable trees. Silvicides, girdling, and cutting have been used in thinning. Vines and cull trees outside the sale areas have been deadened. A considerable portion of this work has been done under the provisions of the Agricultural Conservation Program and its successor, the Rural Environmental Assistance Program. A total of 230 acres has been treated in this fashion.

Trees have been planted to create vegetative snow traps. Conifer trees were used. The trees have not been in the ground long enough to prove their effectiveness in holding snow.

The results of the applied timber-management practices are evident. The forests are healthy and vigorous. The old-growth forest is being replaced by younger better-formed trees. Reproduction in the openings is vigorous. Stocking of trees is good, and species composition is improving.

## WATER PRODUCTION

We have little data about the effect of forest manipulation on water yields on the Westfield properties. This is a working forest, not an experimental forest. Lessons learned in watershed research in other parts of the Northeast are used where applicable and as conditions permit and usage and needs demand.

Techniques used to manage the forests fall into two categories. First, practices that watershed researchers have found effective for increasing water yields are used. Second, standard silvi

cultural methods are applied in many portions of the forest. Changes in water yields as a result of the practices applied are not now measured, and we have no plans for installing measuring devices.

In 1967, John Osborne and A. R. Eschner of the State University of New York College of Environmental Sciences and Forestry at Syracuse made a study to determine the effects of timber harvesting on soil moisture in the watershed. The study resulted in some interesting observations and excellent recommendations for increasing water yields.

## FINANCES

Before forest-management practices were initiated on this forest, ad valorum taxes were paid yearly as they still are. It is difficult to place a dollar value on increased streamflow resulting from forest-management activities. Income from other sources, however, is merely an accounting matter. Expense and income records have been maintained for the forest activities since management began in 1962.

All professional forest-management service costs to date total $9,837. This includes inventories; boundary-line work; management plans; road design, layout, and maintenance supervision; land acquisition; inspections; tours, and consultation. Boundary signs were purchased for $194. Timber-marketing and harvest-inspection fees totaled $6,562. Road maintenance and erosion-control expenses amounted to $703. The total expenses were $17,296.

Capital improvements, land acquisitions, and easements incurred expenditures. About 2 miles of forest road was constructed, and easements were purchased for $6,900. Timber-stand improvement was done on 225 acres for $4,977. Tree planting cost $799. Five properties of 290 acres adjoining the forest were purchased for $14,101. Total capital expenditures totaled $26,777.

Income resulted from federal cost-sharing in the ACP and REAP. Cost sharing from timber-stand-improvement work totaled $3,779. Tree-planting cost sharing was $275. Timber sales revenue was $54,186. Total income since 1963 to date is $58,240.

Income over direct expenses, not including land taxes, is $40,944. When adding the capital expenditures to the expenses and deducting the sum from the income, there remains a cash balance of $14,167.

The forest is due to be reinventoried in 1974.

There now seems to be more sawtimber on the Village property than in 1963. This sawtimber is more valuable than what was present in 1963. Because of the valuable timber resource on this forest, it appears possible to achieve sound watershed management and allow timber production to pay the costs.

## PRESERVATIONISTS & RECREATIONALISTS

Certain timber-management policies have evolved as a result of pressure from preservation-oriented groups. Some fishermen have been upset about timber-harvesting practices. There is repeated pressure to turn portions of the Chautauqua Creek watershed, including the Village lands, into a public park. Recently a public hearing was held in Chautauqua County to amend the New York State Wild, Scenic and Recreation Rivers System Law to include Chautauqua Creek.

The Westfield BPU has steadfastly withstood efforts to remove the property, or its control, from their jurisdiction. It is time-consuming and expensive to engage in public-relation efforts to explain and demonstrate the importance of the Village lands to the protection and production of the Westfield water supply, but the BPU feels that this effort is worthwhile.

Certain accommodations have been made with the recreation public. The lands are not posted. Hiking along Chautauqua Creek is permitted. Fishing and hunting are permitted. Picnickers use the property. Tree screens are left along Chautauqua Creek and public roads. The current policy is to allow these recreational activities, but if the users become destructive or their presence becomes detrimental to water quality, then trespassing will not be permitted. It will be exceedingly difficult to stop recreational trespassers if and when it becomes necessary to do so.

## CONSULTANT'S ROLE

Forestry consultants are prepared to participate in the management of municipal watershed forests. Municipalities with small (100 acres) to medium (10,000 acres) watershed forests may find it difficult to justify the expense of a full-time watershed forester. An advantage in employing a consulting forester is that his fees are based on specific work performed and he is not a full-time municipal employee.

Consultants and their employees are covered by the normal insurances required by state and federal laws. Most consultants are covered by general liability insurance, error and omission insurance, and manufacturer's liability insurance.

Most consultants bring to a job considerable experience in forestry. Many are versed in the practices of sound watershed management. Forestry consultants are generally well informed about forest product markets and know how to sell forest products to bring the best prices possible. They understand logging, the problems, and what can and what cannot be logged. They can generally locate boundary lines and engineer access roads; they have a working knowledge of and license for using silvicides and herbicides. Consultants understand the language and important aspects of timber-sale contracts, and they can be helpful in the development of watershed policies.

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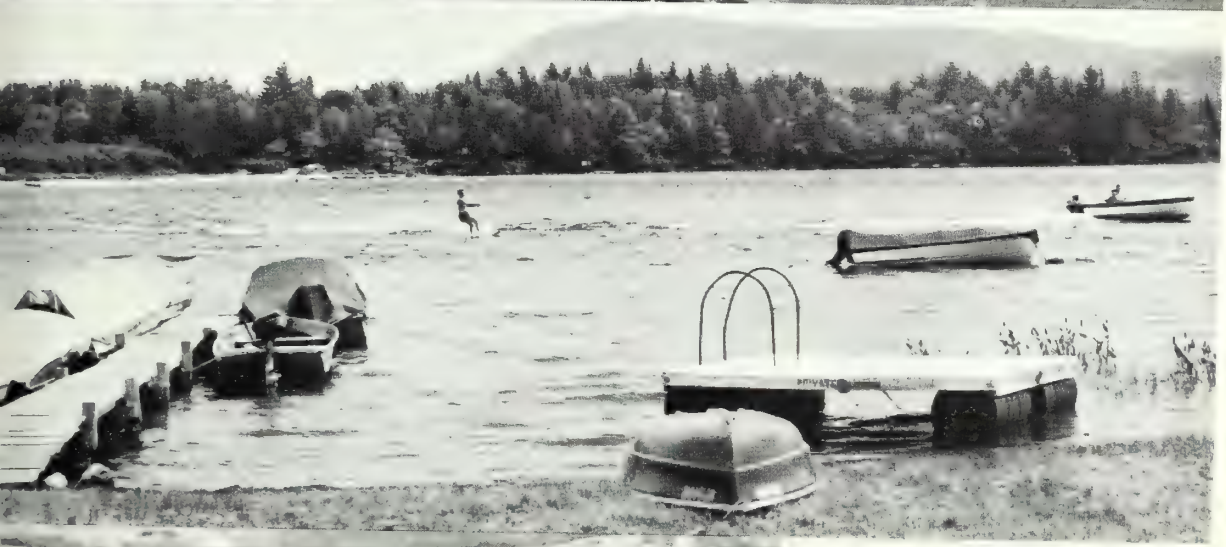
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# MEETING CURRENT AND FUTURE DRINKING-WATER QUALITY STANDARDS

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*ABSTRACT.* Drinking-water standards were first adopted by the United States Public Health Service in 1914. Theoretically, these standards are applicable only to suppliers who provide water for common carriers operating interstate. Practically speaking, however, they have been endorsed by the American Water Works Association and are enforced by most state departments of health. The 1914 standards were revised in 1925, 1942, 1946, and most recently in 1962. This last revision includes, for the first time, limiting concentrations of radioactivity in water and other substances that have become significant because of our accelerating technology. Standards are again under revision. But this time an effort is being made to legislate them so they will legally apply to all waters throughout the country. Three bills, now under consideration by Congress, emphasize state enforcement responsibility but give the federal government authority to step in where states fail to act.

WATER IS ONE of the essentials of life, and the importance of assuring a clean and safe supply of water to the American people for drinking and other uses was never greater than it is today. Just about every activity we can think of involves the use of water. It is used for drinking, cooking, bathing, washing, laundering, heating, air conditioning, agriculture, stock-raising, industrial processes, water power, fire protection, disposal of wastes, swimming, fishing, and boating.

Obviously the water quality required varies for these different uses; what is satisfactory for one use may be completely unsatisfactory for another. One example is chloride content: it should not be greater than 250 mg/l in drinking water; but it must be less than 1 mg/l in modern ultra-high-pressure steam boilers.

There was a time, perhaps, when one could drink water directly from a stream or river and not be adversely affected by it. But that day is long past. It would be very difficult now to find any surface source that is not polluted to some extent. Even groundwaters are not immune from pollution and contamination. In primitive times, when populations were small, human wastes and other impurities were readily assimilated by rivers and streams. But the tremendous amounts of pollutants, including many sophisticated chemicals we discharge daily into our watercourses, have overtaxed those water's ability to absorb the pollutants.

## A NATIONAL EFFORT

With the passage of the Federal Water Pollution Control Act and its 1972 amendments (Public Law 92-500), a real effort is being made to clean up our Nation's waters. The objective of the Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." In essence, the new law requires that every company discharging water into any waterway must receive a permit from a state agency that will set emission limits under EPA guidelines. By 1 July, 1977 companies will have to employ the "best practicable control technology", and by 1 July, 1983 they will have to use the "best available technology." The ultimate goal, although not enforceable under the law, is the complete elimination of water pollution — zero discharge — by 1985.

This is Utopia, and, according to many, it is not attainable. Among the experts who believe it is not is Philip Abelson, President of the Carnegie Institution. Abelson recently pointed out that "the enthusiasm for environmental perfection will double or triple the prices of gas, gasoline and heating oil in a few years." Further, he said, "Americans are right to want to lower pollution, but it is unrealistic to strive for no pollutants at all. The earth would be polluted even if no man lived on it."

Naturally, the cleaner the raw water source, the easier it is to produce a quality finished product from it. But with the technology available today it should be possible to take almost any water source, even though it is highly polluted, and manufacture it into a product that meets the U.S. Public Health Drinking Water Standards — provided people are willing to pay the cost.

Just what do we mean by quality water? According to the American Water Works Association *(1971)*, it is "those chemical, physical, biological or radiological characteristics by which one evaluates the acceptability of the water." The term *quality* is relative, depending upon the use of a particular water. What is a good quality water for one purpose may be of poor quality for another. The only way we can evaluate the quality of a water is to compare the concentration of the various constituents present in it with standards.

In 1880, under the direction of J. W. Mallet, the National Board of Health began a study of various tests that had been suggested for determining pollution in water. A report of this work, published in 1882, pointed out, among other things, that "it is impossible to judge the sanitary character of drinking water by any methods of chemical analysis investigated." And further, "there are no sound grounds for establishing standards of purity based upon the amounts of certain constituents present."

At this time bacteriological procedures were not even as far advanced as chemical methods. In fact, the German biologist, Emmerich, tested polluted waters, not by chemical or bacteriological methods, but by swallowing samples of water and by feeding them to animals. A positive test was the onset of fever or other physiological changes—sometimes even death. During the next 30 years, various laboratories throughout the country established their own chemical standards for potable water. And meanwhile, useful bacteriological procedures were developed.

On 21 October, 1914, upon recommendation of the Surgeon General of the Public Health Service, the first bacteriological standard for drinking water was adopted by the Treasury Department. Those who developed this standard were 15 leading chemists, bacteriologists, public health experts, and sanitary engineers. The standard applied only for

water supplied to the public by common carriers in interstate commerce. It is interesting to note that, during development of the bacteriological standard, considerable discussion took place about whether it should also include a statement that water shall "be free from injurious effects upon the human body and free from offensiveness to the senses of sight, taste or smell." So it is obvious that even in those early days some thought was given to chemical and physical parameters.

The bacteriological standard was in two parts: First, the total bacteria count on agar plates was not to exceed 100 organisms per ml. And second, not more than 1 of the 5 portions planted in lactose broth shall show the presence of B. coli.

#### *Standards Revised*

The first revision of the standard took place in 1925 when the plate count was eliminated and the B. coli count was further refined. In this revision there were recommended limits for color, chlorides, iron, magnesium, and sulfate. The water was to be clear, colorless, odorless, pleasant to the taste, and was not to contain an excessive amount of soluble mineral substances or any chemicals used in treatment processes.

By 1942 our knowledge about the effect of various impurities in water on humans had increased sufficiently that changes in the standards were again indicated. This time there was a distinct separation of the text into two parts — one part containing the standards and the other the Manual of Water Works Practice. Both the bacteriological and chemical sections were updated and expanded. One key addition was the requirement that a minimum number of samples, depending upon the population served, was to be examined each month. In addition, laboratories were subject to inspection.

The main difference in the 1946 standards was the removal of the Manual of Recommended Water Sanitation Practices and its issuance as a separate publication.

In 1962 the standards were revised again. Although the bacteriological section was left essentially the same as it was in the 1942 revision, the membrane-filter technique for bacteriological examination was permitted for the first time. The number of samples that have to be collected each month, based on population served, was increased. A number of changes were made in the recommended limits for chemical constituents, and new constituents were added. For the first time, limits for radioactivity were included; and values that should not be exceeded were given for them.

The 1962 standards (table 1), are the ones we use today. Officially they are still applicable only to the approximately 800 municipal water supplies that provide water for loading on common carriers operating interstate. Practically, however, they have been endorsed by the American Water Works Association and have been adopted by most state departments of health. Thus, in general, they have been accepted for use by all public water suppliers throughout the country.

During the last couple of years a rather extensive revision of the 1962 standards has taken place. The actual work has been done by a technical committee with the help of a public advisory committee. Originally the revised standards were scheduled to be issued in 1972. But they were held up pending action in Congress, because, for the first time, safe drinking-water bills have been introduced in both the House and Senate. HR 1059 was introduced in the House

Table 1.—U.S. Public Health Standards for Chemical and Physical Characteristics of Potable Water

| Substance | 1962 | | Proposed 1973 | |
|---|---|---|---|---|
| | Recommended limits | Tolerance limits | Esthetic limits | Health limits |
| | *Mg/l* | *Mg/l* | *Mg/l* | *Mg/l* |
| Alkyl benzene sulfonate | 0.5 | — | — | — |
| Arsenic | 0.01 | 0.05 | — | 0.1 |
| Barium | — | 1.0 | — | 1.0 |
| Cadmium | — | 0.01 | — | 0.01 |
| Chloride | 250 | — | 250 | — |
| Chromium | — | 0.05 | — | 0.05 |
| Color | 15* | — | 15* | — |
| Copper | 1.0 | — | 1.0 | — |
| Cyanide | 0.01 | 0.2 | — | 0.2 |
| Fluoride | 0.6–1.7 | — | 0.6–1.7 | 1.4–2.4 |
| Foaming agents | — | — | 0.5 | — |
| Iron | 0.3 | — | 0.3 | — |
| Lead | — | 0.05 | — | 0.05 |
| Manganese | 0.05 | — | 0.05 | — |
| Mercury | — | — | — | 0.002 |
| Nitrate (as $NO_3$) | 45.0 | — | — | 45 |
| Odor (T.O. No.) | 3* | — | 3* | — |
| Organic-carbon adsorbable | — | — | — | — |
| CCE | 0.2 | — | — | 0.7 |
| CAE | — | — | — | 3.0 |
| Phenols | 0.001 | — | — | — |
| Selenium | — | 0.01 | — | 0.01 |
| Silver | — | 0.05 | — | 0.05 |
| Sulfate | 250 | — | 250 | — |
| Total dissolved solids | 500 | — | — | — |
| Turbidity | 5* | — | — | 1.0* |
| Zinc | 5.0 | — | 5.0 | — |

*Units

by Congressman Paul Rogers and S433 was introduced in the Senate by Warren Magnuson. In addition, the administration has also introduced a bill. Although there are some differences in these bills, they all establish, by law, national drinking-water standards in two categories: primary constituents related to protection of the public health; and secondary constituents (esthetics) that effect the senses — taste, odor, and general appearance of the water. The proposed standards are also listed in table 1. According to all three bills, the states will have the primary responsibility of enforcing the standards, but EPA is authorized to step in in case the states fail to act.

On 5 June the Senate Commerce Committee, after many hearings, ordered S433, with several amendments, reported out on the floor of the Senate, where it was passed. That is the status at this time, although we have every ex-

pectation that the standards will become law sometime in 1973. It actually became law in December 1974.

Neither the current nor proposed standards represent a high-quality water. Instead they establish "the furthest deviation from purity considered permissible, so that the health of the public can be protected" *(Buswell 1951)*.

For those who want to produce a high-quality water — and we all should — there are *Quality Goals for Potable Water* to use for comparison *(Bean 1968)*. Established by the American Water Works Association in 1965, these goals (table 2) are "substantially more exacting than existing (and proposed) Drinking Water Standards with respect to both health and esthetic qualities. They are generally attainable by correct application of known treatment processes and methods."

Table 2.—Ideal Quality Water
[A.W.W.A.]

| Item | Criteria |
|---|---|
| Turbidity | Less than 0.1 scale units |
| Non-filterable residue | 0.1 Mg/l |
| Microscopic and nuisance organisms | None |
| Color (true) | 3 units |
| Odor | No change on carbon contact |
| Taste | None |
| | *Mg/l* |
| Lead | 0.03 |
| Barium | 0.5 |
| Fluoride | Variable inversely to temperature |
| Arsenic | 0.01 |
| Cyanide | 0.01 |
| Silver | 0.02 |
| Selenium | 0.01 |
| Cadmium | 0.01 |
| Chromium (Hexavalent) | 0.01 |
| Iron | 0.05 |
| Aluminum | 0.05 |
| Manganese | 0.01 |
| Copper | 0.2 |
| Nitrate (N) | 5.0 |
| Filterable residue | 200 |
| Zinc | 1.0 |
| Phenolic compounds (as phenol) | 0.0005 |
| Chloroform Sol. from carbon adsorption | 0.04 |
| Alcohol-soluble material from carbon adsorption | 0.10 |
| Alkyl benzene sulfonate (ABS) | 0.2 |
| Hardness (as $CaCO_3$) | 80 |
| Coupon tests (90 day) | |
| Stainless steel | Not to exceed 0.01 mg/sq cm |
| Galv. iron | Not to exceed 5.0 mg/sq cm |
| Coliform (multiple-tube or membrane filter) | 1 per liter |

NOTE: All figures above are maximum concentrations in ideal water.

These then are the drinking water standards and the water quality goals. The questions are: First, can we treat highly polluted and contaminated waters to bring them into conformity with the standards and goals? And, second, if we can, what kinds of treatment do we have to use?

## PRICE IS THE KEY

There are two schools of thought on these questions: One is represented by Leonard B. Dworsky, director of the Water Resources and Marine Sciences Center at Cornell University. Recently in testimony before a Congressional committee, Dworsky said that "chemicals in our natural water supplies and in our drinking water supplies is a matter that has not been given enough consideration by this Nation, by our water supply industry or by the water pollution program." . . . "I am afraid," he said, "we are at the stage whereby some day — and it might be very close — we might have one overly harmful chemical pass through this thin wall in an amount dangerous to humans. We cannot emphasize too strongly that our present technology is not capable of taking out many of the contaminants that exist in the surface waters of the United States, or in the ground water."

Then, too, Shuval and Gruener *(1973)* writing in the July issue of *Environmental Science and Technology,* expressed their concern about trying to produce a quality water from waste water, either direct or indirect. They pointed out that "the mere comparison of the quality of the final effluent against those standards currently listed in USPHS Drinking Water Standards leaves too many questions unanswered to be accepted as adequate evidence that such an effluent is completely safe from the public health point of view."

On the other hand, Hartung and Tuepker *(1969)* believe that "theoretically any raw water can be processed into quality water." They did point out that the procedures used might have to be specialized industrial techniques that go beyond those now considered feasible for public water-supply application. And Abel Wolman, that dean of water works men, recently wrote that: "one can undoubtedly produce any tailor-made water the consumer needs or desires. The important questions in each instance remain as to when, where, why and at what price" *(1970)*. The key word is price. People must be willing to pay a lot more than they do now if they want a quality product from a highly polluted source.

Unfortunately, too many plants today use only conventional water treatment processes consisting of coagulation with aluminum sulfate (alum) or one of the iron salts, sedimentation, rapid sand filtration, and disinfection with chlorine and ammonia to form one or more of the chloramines. Actually, in many cases more specialized kinds of treatment are necessary to reduce the concentration of pesticides and other organic compounds, fluorides, nitrates, and the so-called heavy metals (lead, arsenic, cadmium, and mercury) to acceptable limits. Such processes as aeration, adsorption, oxidation with chlorine, chlorine dioxide, ozone or potassium permanganate, filtration through granular carbon beds, ion exchange, and even distillation or reverse osmosis may be necessary.

At this point I shall select several impurities, or classes of impurities, known to exist in water-supply sources, and show how various treatment processes can be used to reduce their concentration to a long-term safe level.

### *Turbidity*

All surface supplies contain some turbidity, due to clay and silt from land

erosion, finely divided organic matter, algae, and other microscopic organisms. Although the larger particles will settle by gravity, colloidal matter will not. It requires destabilization by one of the polyvalent metal salts — aluminum sulfate, ferric sulfate or ferrous sulfate and chlorine, or a cationic polyelectrolyte — followed by sedimentation and rapid sand filtration. The process is known as coagulation/flocculation.

Although the present drinking-water standard for turbidity is 5 units, it has been reduced to 1 unit in the proposed standards. The AWWA Water Quality Goals limit turbidity to 0.1 unit.

The presence of turbidity is undesirable esthetically. But it also has indirect public health significance. For example, Hudson *(1962)* has shown that turbidity and microorganism removal generally parallel each other. Moreover, the incidence of viral disease and the degree of clarification attained, as indicated by measurements of filtered water turbidity, also parallel each other. Riddick *(1961)* has shown a similar relationship between the removal of colloids by coagulation and tastes and odors.

Few studies have been made on the removal of algae by conventional treatment. In 1961 Borchardt and O'Melia reported that algae are removed not only at the surface but throughout the bed of the sand filter. As a result, some algae always pass through the filter during its operation. More recently, work by Speedy, Fisher, and McDonald *(1969)* indicated a wide disparity in the efficiency of algae removal by various unit processes. For example, sedimentation basins, following coagulation, were found to remove an average of 37 percent of the algae. Addition of chlorine had no appreciable effect on removal, even though it killed the algae. Softeners showed a fairly high degree of removal with 50 to 100 organisms per ml in the effluent regardless of the number in the influent. Best removal occurred with the use of lime, without alum, for both clarification and softening (97 percent removal). Experiments performed in Philadelphia Suburban Water Company laboratories showed that coagulation with iron salts, followed by sedimentation, is much more effective than aluminum sulfate in removing algae. This is undoubtedly due to the heavier iron floc that forms. Certainly there is no reason why a well-operated plant, using only conventional treatment, can't consistently produce a water with an effluent turbidity of less than 0.2 units.

#### *Bacteria*

Present standards do not have a limit on total plate count. However, it looks as though the proposed standards will have a limit of 500 organisms per 1 ml when the agar plates are incubated for 48 hours at 35°C. Total counts include some pathogenic organisms as well as a variety of nonpathogenic organisms, some of which can become serious secondary pathogenic invaders in postoperative infections. Pseudomonos, Flavobacterium, Klebsiella, and other organisms can act in this way.

The bacteriological quality of a water is presently determined by the presence or absence of coliform organisms. This group is defined in *Standard Methods (1971)* as including all the aerobic and facultative anaerobic, gram-negative, non-spore-forming rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C. Harmless themselves, they serve as indicator organisms. They are always present in the intestinal tract of humans and warm-blooded animals and they are eliminated in large numbers in fecal wastes. If coliform bacteria are absent in a sample of water, chances are that water is free from waterborne disease organisms such as typhoid fever, paratyphoid fever dysentery, and cholera.

The 1962 bacteriological standards require that when 10-ml standard portions of a sample are examined, not more than 10 percent in any month shall show the presence of the coliform group. And further, the presence of the coliform group in three or more 10-ml portions of a standard sample shall not be allowable if this occurs:
(a) in two consecutive samples, (b) in more than one sample per month when fewer than 20 are examined per month, or (c) in more than 5 percent of the samples when 20 or more are examined per month.

Coliforms and the pathogenic organisms often associated with them are readily destroyed by the right dose of chlorine — provided it's in the free available state and sufficient contact is given. An important point to remember is that turbidity can act as a shield, thus protecting the organisms from contact with chlorine.

When small amounts of chlorine are added to water, a reaction occurs with ammonia whether present or added, to form monochloramines and dichloramines. Both compounds are relatively poor disinfectants. When more chlorine is added, however, (about an 8:1 ratio) the ammonia is oxidized and a free available chlorine residual results. This is a potent disinfectant, one that will destroy all pathogenic organisms if a residual of 0.5 mg/1 is maintained for at least 30 minutes. Other useful disinfectants are ozone, chlorine dioxide, and iodine.

### *Viruses*

A virus can be defined as a microorganism considerably smaller than a bacterium and capable of multiplying only within the living cells of a susceptible host. There are many viral diseases, any one of which theoretically can be transmitted from person to person by water. But up to now infectious hepatitis is the only viral disease proven to be waterborne. Unfortunately no satisfactory method has thus far been developed for determining either the presence or quantity of virus in a water supply. For this reason no standards have been developed, nor are any planned for the 1973 revision.

Most experimental work has shown that viruses are more resistant than bacteria to chlorination and other treatment processes. Thus the coliform standard may not necessarily apply to viruses. Fortunately the ratio of coliforms to virus is large: 92,000:1 for sewage and 500,000:1 for polluted surface water.

We do know, however, that there are a number of treatment processes that, if used together, are effective in producing virus-free water. In work done at the University of Illinois, Chaudhuri and Engelbrecht *(1970)* demonstrated that good chemical coagulation and flocculation are effective in removing between 98.0 and 99.9 percent of the viruses present. But they found that the removal efficiency decreased in the presence of organic matter.

Experience has shown that different enteric viruses show wide variations in their resistance to chlorine. Yet Clarke and Chang *(1959)* found that all enteric viruses they studied were destroyed by a free chlorine residual of about 1.0 mg/1, provided a contact time of at least 30 minutes is used. Around a pH of 7.0, activated carbon has the ability to adsorb some viruses. And a recent report indicated that diatomaceous earth filtration, preceded by polyelectrolyte feed, is capable of removing up to 99 percent of T2 virus for Escherichia coli B.

It would appear from these studies that a combination of the processes — coagulation, flocculation, sedimentation, filtration and chlorination with free available chlorine (or other viricide) — will destroy all viruses likely to be present in a water source.

### *Mercury*

A German chemist, Alfred Stock, spent most of his career testing for and finding mercury in almost everything he tested. Up until his death in 1946 he tried in vain to alert his fellow scientists to the dangers of mercury. Now his ignored warnings have become a matter of concern to people all over the world.

Four weeks after Stock's death, fishermen and their families and pets around Minamata Bay, Japan, were stricken with a mysterious illness. The symptoms included muscle weakness, loss of vision, impaired cerebral functions, and eventual paralysis. In more than 40 cases coma and death were the end result. Since the people, birds, and animals who had the disease subsisted mainly on fish, this product was examined as a possible source of the trouble. High concentrations of mercury were found in both fish and shellfish, and its origin was traced to a factory effluent.

Since then there have been other incidents involving mercury. One of these that received a great deal of publicity in the press was the discovery of high mercury concentration in fish in Lake Saint Clair. Restrictions were immediately imposed on fishing and on the sale of fish from this lake. The source of the mercury was found to be several electrolytic chlorine manufacturing plants, each of which was releasing between 5 and 60 pounds of mercury to the water every day. Further investigation disclosed that there were high mercury levels in the waterways of 33 states, and 18 states imposed some restrictions on water use.

Mercury is used in the manufacture of electrical equipment and control instruments; as a biocide in agricultural products; in pulp, paper, and paint manufacture; in pharmaceutical and dental preparations; as a catalyst; and in chlorine production. Moreover, the element is found in trace amounts in the atmosphere, in rocks and soil, and in the tissues of plants and animals.

The mercury compound found in seafood was more toxic than the usual inorganic compounds. This was finally explained by the fact that inorganic mercury is biologically converted to the much more toxic organic methyl mercury by microorganisms in water. After ingestion, plants and animals tend to concentrate this organic mercury in their tissues. So when algae consume mercury compounds, they concentrate it many times over what it is in the water in which they live. When fish eat algae, they further concentrate the mercury — and so this concentration continues up the biological ladder.

Although the FDA has recommended a maximum limit of 0.5 ppm for fish, none of the drinking water standards thus far have included a limit for mercury. The proposed standard, however, sets a limit of 0.002 mg/1 in water.

Compounds of mercury, especially those that are soluble, are difficult to remove from water. However, if they are present in an insoluble form, a substantial concentration will most likely be removed by conventional treatment. Soluble compounds will require more drastic treatment, such as passage through an ion exchange unit. This process will remove the toxic mercury and replace it with a nontoxic cation.

Studies carried out in the laboratories of Westvaco have shown that activated carbon has good adsorption potential for mercury *(Sigworth and Smith 1971)*. Our own studies with powdered carbon have also established its effectiveness. In one experiment, for example, we found that a dose of 50 mg/1 of carbon reduced the mercury content of a sample of water from 0.01 mg/1 to 0.001 mg/1. Passage through granular carbon filters should do an even better job.

The removal of mercury, and other heavy metals, is also enhanced by those water-softening processes that involve chemical precipitation; for example, lime or limesoda softening. Finally, a recent report indicated that if a water containing divalent mercury is treated with starch xanthate-cationic polymer complex, considerable reduction takes place. Unfortunately, organic mercury compounds are poorly precipitated by this system.

#### *Pesticides*

Paris green (copper acetoarsenite) was probably the first chemical to be used against insects. At about that time (1874), a German chemist synthesized a compound called dichlorodiphenyltrichloroethane (DDT). This chemical sat on the shelf until the late 1930s when Paul Muller, a Swiss entomologist, discovered that it was an extremely effective insect killer.

Other synthetic organic pesticides followed DDT, until in the early 1940s production in the United States was approximately 25 million pounds. By 1970 more than 1,000 million pounds were being produced. These organic pesticides have been most valuable in killing insects known to transmit the organisms responsible for typhus, malaria, yellow fever, plague, and other diseases. At the same time, with the help of Rachael Carson's popular book, *Silent Spring (1962)* people became concerned about possible health risks involved in the use of pesticides and their accumulation in the food chain. This concern increased when it was realized that these compounds were soluble in fat and thus would tend to accumulate in the fatty tissues of plants and animals. A good example was given by Wagner *(1971)*, who reported that an analysis of bottom mud of Green Bay, Wisconsin, showed 0.014 mg/l DDT. Small crustaceans showed 0.41 mg/l (three times as much), fish 3 to 6 mg/l, and herring gulls 99 mg/l. If man were to eat fish with this concentration of DDT, he too could accumulate enough of it to have an adverse physiological effect.

There are two groups of organic pesticides that are dangerous from the standpoint of environmental contamination. The organophosphates and the organochlorines (also called chlorinated hydrocarbons). Parathion and malathion are organophosphates, whereas endrin, heptachlor, aldrin, toxaphene, dieldrin, lindane, DDT, chlordane, and methoxychlor are organochlorines. Because of their persistence, the last group has the greatest effect on the environment.

In the mid 1960s, waters from 99 streams and rivers in the United States were examined for pesticides, and a wide range of values was obtained. Although the Mississippi River water contained 4.23 $\mu$ g/l, others showed only a trace or none at all. The average of all 99 was 0.002 $\mu$ g/l. The source of these pesticides is very likely runoff from agricultural land, industrial waste discharges, the washing of application equipment, and drifting during aerial spraying.

Up until now there have been no standards for pesticides, although there has been much discussion about the need for such standards. In 1965 the Public Health Service advisory committee suggested that certain limits be set for pesticides. Their recommendations, although never formally adopted, served as guidelines in evaluating a water supply. These guidelines and the values proposed for the 1973 standards are shown in table 3. According to Robeck, the proposed standards are based on the latest experimental mammalian data and incorporate a factor of safety of approximately 500.

Evidence from laboratory studies and plant practice indicates that conven-

Table 3.—Pesticides

| Chlorinated hydrocarbons | Old guideline | Proposed 1973 standards |
|---|---|---|
| | *Mg/l* | *Mg/l* |
| Aldrin | 0.017 | 0.001 |
| Chlordane | 0.003 | 0.003* |
| DDT | 0.042 | 0.05 |
| Dieldrin | 0.017 | 0.001 |
| Endrin | 0.001 | 0.0005 |
| Heptachlor | 0.018 | 0.0001 |
| Heptachlor Epoxide | 0.018 | 0.0001 |
| Lindane | 0.056 | 0.005 |
| Methoxychlor | 0.035 | 1.0 |
| Toxaphene | 0.005 | 0.005* |

*Limit selected on basis of odor although the toxic limits are similar.

tional treatment will not remove any significant amount of pesticide, except for DDT. But when Cohen et al *(1960)* studied the effect of various water-treatment processes in reducing the concentration of toxaphene, they concluded that activated carbon was the most effective treatment. A 9 mg/l dose of powdered material removed 95 percent of a 0.3 mg/l concentration. In addition to removing the pesticide, carbon will also adsorb the solvents and emulsifiers usually present.

Later Robeck et al *(1965)* studied the effect of conventional treatment, and powdered activated carbon, but in addition, included chlorine, potassium permanganate, and ozone. They found that DDT was easily removed by coagulation and settling followed by filtration, but lindane and parathion were not. Chlorine and potassium permanganate at 1 to 5 mg/l did not oxidize chlorinated hydrocarbons. Actually parathion was converted to a more toxic compound. Some oxidation occurred with large doses of ozone, but the toxicity of the new compounds is not known. Activated carbon gave the best results, although the dose varied with each pesticide.

A reduction from 10 ppb to 1.0 ppb required 29 mg/l of carbon for lindane, but only 5 mg/l for parathion. In general, it takes more carbon to remove endrin, dieldrin, and lindane than it does to remove parathion. Granular carbon filters were very effective in reducing the concentration of all pesticides studied.

### *To Meet the Standards*

In 1969 the Bureau of Water Hygiene of the Public Health Service made a nationwide survey of community water-supply systems *(McCabe et al 1970)*. The purpose of the survey was to find out if the American consumer's drinking water met the drinking water standards.

And what did they find? Just this:

Out of 969 public water-supply systems, serving about 18.2 million people, 496 do not disinfect, clarify, or buy chlorinated water; 311 do not clarify but only disinfect or buy chlorinated water; 7 clarify but do not disinfect; and only 155 (16 percent) clarify and disinfect.

Is it any wonder then that only 59 percent of the systems inspected met all of the drinking water standards? Admittedly many of the deficiencies were

due to faulty procedures rather than deficiencies in quality of water served. But there were enough systems serving waters with too great a concentration of coliforms, heavy metals, pesticides, or total organic content for us not to be concerned about them. These plants need to incorporate more sophisticated treatment processes, better laboratory control procedures, and more highly trained operators. To do this, a great deal of money will have to be spent. But only by doing this will all plants produce a high-quality water that consistently meets all of the drinking water standards — present and proposed.

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# RECREATION PROBLEMS AND OPPORTUNITIES

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*ABSTRACT.* Demand for water-oriented outdoor recreation continues to increase, especially near urban areas. As these demands rise, municipal watershed managers can expect to feel increased pressure for recreational use of land and water resources under their jurisdiction. The authors discuss some of the problems associated with recreational use of municipal watersheds and present some ideas for managers who anticipate recreational use pressures. Problems and opportunities are reviewed for watersheds on which all forms of controlled recreation are permitted, for watersheds on which no recreation is allowed, and for watersheds that permit only selected types of recreation.

SEVERAL FACTORS have influenced the rate of reservoir construction during the past 15 to 20 years. Flood control, navigation, low-flow augmentation, rising per-capita water consumption, and water-oriented outdoor recreation are the reasons that most people cite. Recreation, of course, is always listed last because it is so difficult to assign a value or benefit to a day's outing on a reservoir. But recreation is often a very important use of new reservoirs.

As the federal government tightens the screws in its attempt to curb inflation, the rate of reservoir construction will slow down. This type of capital expenditure is always a prime target during periods of tight money. But will the rate of increase in water-oriented outdoor recreation slow down? No. Room for recreation, especially on water, will shrink as the rate of reservoir construction diminishes. Reservoirs will become more and more crowded, and managers of municipal water-supply reservoirs can expect to feel increased pressure to allow recreation on the land and water resources under their jurisdiction.

A recent nationwide survey of resource development indicated that most forms of recreation will be allowed on municipal watersheds by the year 2000. This national trend may or may not reflect the future situation in the Northeast. Growing pressure is sufficient justification for investigating expected problems and opportunities associated with recreation on municipal watersheds.

The problems and opportunities are those that have been found on watersheds operated under an open-door policy, under which all forms of outdoor recreation are permitted under super

vision. Also, problems and opportunities might be encountered on watersheds that do not allow recreation, and on watersheds where selected activities are permitted.

With a mandate to provide a safe and adequate supply of water, we can eliminate equalizing reservoirs from our discussion. Likewise, terminal reservoirs could be eliminated.

Class-C upstream reservoirs generally are multiple-use reservoirs. Recreation commonly occurs on Class-C reservoirs. Class A and B upstream reservoirs contain water derived from sparsely inhabited areas; they are near the point of rainfall or snowmelt, and water from them generally is considered clean enough to consume with minimal treatment. Water in them is considered ideal for water-oriented outdoor recreation. But recreation is restricted or prohibited on them. Class A and B upstream reservoirs are where watershed managers can expect to feel pressure for recreational use in the future.

Recreation activities that have impacts on watersheds might be classified as either land-based, such as hiking, photography, and bird watching; or water-based, such as swimming and boating. Land-based recreation activities do not present much of a problem as long as the carrying capacity of the land is not overtaxed. Water-based recreation requires much closer scrutiny because it is often more detrimental to the water resource and is usually done by greater numbers of people.

## WATERSHED WITH OPEN-DOOR POLICY

We have defined a watershed with an open door policy as one on which all forms of recreation are permitted under controlled conditions. Development or construction of facilities on the watershed must be reviewed and approved by a board or agency; most forms of recreation activities such as swimming, waterskiing, and camping are permitted at specified areas under proper supervision (fig. 1).

The most obvious problem one thinks of when discussing the watershed with an open-door policy is the need for upgraded water treatment facilities. The prime objective of the water-supply system is to provide an adequate supply of potable water; and if recreation is to be permitted, full treatment of the water will probably be necessary. In many cases, this amounts to increased levels of

Figure 1.—An open-door policy permits all forms of recreation on reservoirs under controlled or supervised conditions.



disinfection, new equipment, and possibly higher paid personnel to operate and maintain the equipment. What this all boils down to is a larger water-supply budget *(Price 1966)*. An immediate side effect might be a change in water color or taste.

If a municipality permits all forms of controlled recreation on its water-supply reservoir, some form of recreation facility development will be required. Recreationists' needs will have to be accommodated by provision of facilities. Should toilet facilities be primitive or modern? How many and where should toilet facilities be placed? Who should pay for taking care of recreationists' needs on a municipal watershed? If the recreationist is to pay, how much should he pay and how will fees be collected?

All forms of controlled recreation include swimming and boating. Is the reservoir large enough to support a marina? Should power boats be allowed? If so, should horsepower limits be imposed? Should swimmers have a beach, change house, snack bar? What kind of recreation staff will be needed?

Not only will more money be needed to maintain an adequate and safe water supply, but recreation-facility developments and maintenance might put a heavy strain on present levels of municipal appropriations. Finally, under an open-door policy, the budget for recreation management might become greater than the water-supply management budget.

In addition to financial problems, a second set of problems arises in management. Consider the water purveyor suddenly becoming a team leader who must deal with people problems such as clogged toilets, drownings, or broken playground equipment. If he is not able or willing to take on the added responsibility, he will have to arrange for an assistant to handle the job. The water-supply superintendent must then be careful not to permit recreation objectives to overwhelm the water-supply objectives of the organization *(Reigner 1965)*.

The political attractiveness of a recreation program presents a very real threat to the primary objective of a water-supply system. Recreation personnel are liable to raise issues that conflict with the original purpose of a reservoir. Policy conflicts may be compounded by philosophies, background orientation, or personality conflicts that tend to detract from the organization's total program effectiveness.

Public-relations problems must also be considered by the reservoir manager. If a town decides that all forms of recreation will be allowed, the needs of the recreationist must be considered in every management decision. This new clientele desires such things as steady water levels, easy access, and some sort of a developed recreation program and facilities.

A midwestern water-supply superintendent provided an example of what happened when all forms of controlled recreation were permitted. He felt that water-supply objectives had become secondary to recreation objectives on a 3000+-acre reservoir that served a community of nearly 15,000 residents. Three camping areas had been established. Some trailers were located less than 150 feet from the reservoir shoreline. The seasonal campers used buried 50-gallon drums to hold sanitary waste. The drums are supposedly pumped out once per week.

Lake frontage was leased around the lake, and construction of seasonal docks was allowed. Camps soon appeared all around the reservoir, and the lake's boat marina now has many empty slips. Road access to the new sites had been encouraged by providing gravel on trails hacked out of the woodland that surrounds much of the reservoir. Waste dis-

posal on these dispersed campsites was not controlled at all.

Recreational use of the reservoir provided some additional revenue to the city, and continued development seems imminent. In many instances advice and suggestions of the lake recreation supervisor are heeded by the city council over opposing views of the water-supply superintendent.

Despite these problems on the reservoir property, the water-supply superintendent hastened to point out that his major problem was with the landowners in the watershed. The estimated life of the 15-year-old reservoir is another 10 to 12 years, at which time siltation is expected to render it useless. If simple, and in many cases basic, soil-conservation measures were to be started immediately, the siltation problem could be decreased by 50 percent. Recreation problems, although very real, appeared to be a mere thorn in the side compared to the impending siltation of the lake.

On the plus side of the situation, the water-supply superintendent was confident that, when siltation finally caused abandonment of the present reservoir, the local populace would not hesitate to find another site for a new reservoir.

One opportunity available to managers of municipal watersheds that have an open-door policy is the expanded base of support for the water-management program. This support is often at the grass-roots level.

Managers sometimes have trouble stimulating interest on water management issues. As an example, the director of utilities for San Diego said that there had never been any negative reaction from the general public about their program — which, by the way, has as its main purpose "to maintain a high quality domestic (water) supply" *(Graham 1963)*. "On the other hand", he went on to say, "thousands of sportsmen are boosters for the municipal water supply and its administration."

As mentioned earlier, one of the problems associated with an open-door policy is that the watershed manager finds himself in a different ball game — different clientele, different sets of problems, different types of personnel, and different financial obligations. For the man that appreciates the challenge of managing a multidisciplinary team, an open-door policy can provide the opportunity of a lifetime to make a meaningful contribution to the well-being of his community. Chances are that he will be the only man in the community who has a real feel for the needs of safe and potable water (and all that that entails) and the many needs for a developing recreation program.

This opportunity may not be just the challenge of a lifetime for an individual: it may be the turning point in a water-supply organization's history from one of providing water to a dynamic multipurpose service to the community. Under the proper supervision and administration, recreation may become a vehicle for improving a water-supply organization's financial status without indirectly detracting from a watershed's ability to produce high-quality water.

## WATERSHED WITH CLOSED DOOR POLICY

In some cases a municipal watershed ecosystem will be unable to accommodate recreation activities. This could be so when funding for a modern water-treatment plant is not available or the watershed is in a geomorphic area of shallow or fragile soils.

The decision to prohibit all recreation on the watershed must be based on factual information. The watershed manager and the water-supply governing board must have valid justification for their decision. Citizen groups are active in many areas of the recreation field, and



Figure 2.—A closed door policy need not preclude all forms of outdoor recreation or educational activities such as nature walks.

any decisions to exclude recreation may come under very close scrutiny.

As long as population growth and the demands for water-oriented recreation space continue, the pressure for greater use of watershed areas will be a problem. Continued and strong justification will be needed to cope with the problem. The watershed-management staff should not attempt to do their own police work. Police enforcement should be handled by state and local groups. A significant element of expense will be incurred in the construction and maintenance of fences, road blocks, signs, and other facilities. A segment of people, hopefully small, may be expected to disobey the exclusion regulation.

By definition, a watershed with a closed-door policy on recreation should have no problems. But as we have pointed out, there are problems. There are also opportunities. For instance, if people are truly kept out of an area, that area soon may become a refuge for wildlife. It may also be considered a natural area in which environmental monitoring can be carried out.

The reservoir itself provides an amenity that is difficult to price, but nevertheless has value. And herein lies an opportunity for the alert watershed manager to tell his story of why recreation would be detrimental to the well-being of the community. People seem to be more activated by signs that proclaim RECREATION PROHIBITED rather than by signs stating RECREATION PERMITTED, particularly if public land is involved.

An information booth located outside the watershed boundary, but still commanding a view of the reservoir and parts of the watershed, could inform interested citizens of the water problems as well as the values to be derived from not recreating inside the boundary. This may then become the starting point for a nature trail along the boundary edge (fig. 2).

### WATERSHED WHERE SELECTED ACTIVITIES ARE PERMITTED

A watershed where selected activities are permitted is defined as one on which non-polluting recreation activities are permitted. These may include activities such as fishing from shore or from rowboats, hiking, and picnicking at designated areas away from the shoreline. Generally speaking, activities such as swimming, boating in sailboats or canoes that may capsize, powerboating, and other potentially polluting activities are prohibited *(Reigner and Ningard 1967)*.

Any kind of access to a water-supply reservoir results in a chance of contamination. Most managers will do all they can to reduce or eliminate that chance. Therefore selected activities on a reser-

voir would be a strong incentive to provide water treatment. In a study of municipal water-supply areas in Maine, Monteith and Corcoran *(1967)* concluded "that institutional, political and social considerations probably weigh more heavily" than treatment considerations in the decision of whether or not to allow recreation on water-supply reservoirs. Bauman *(1969)* found a regional variation in recreational use of domestic water-supply reservoirs. Reservoirs in the South and mid-continent have policies that tend to permit recreation while those in the Northeast and far West have policies that tend to prohibit recreation. Foster *(1961)* felt that in Massachusetts "the chief barrier to the relaxation of restrictions governing public use of water supply reservoirs would appear to be, on the surface, not technological but legal." As Commissioner of the Massachusetts Department of Natural Resources he favored "voluntary sensible change", rather than "crisis action."

The problems encountered on areas that allow only selected recreation activities may not be much different from those that arise on areas that allow all forms of recreation or those that allow no recreation. If access is permitted on a watershed for selected activities, enforcement efforts are needed to prevent the visitor from engaging in excluded activities. For instance, bank fishing may be permitted, but boys have been known to "fall" into the water on a hot summer day. The big question then becomes: How many boys can be tolerated before pollution levels become dangerous?

In a review of five studies carried out between 1960 and 1967, Carswell et al *(1969)* described some of the problems encountered on watersheds that permitted selected types of recreation. Body contact with the water was prohibited in all cases. Shoreline litter was found, ranging from bait containers to human defecation. Evidence was abundant that visitors abused the privilege of access by building illegal fires, cutting down trees, destroying signs and other property, and shooting up signs and other property (fig. 3). When administrators attempted to enforce rules of conduct, they were rebuffed by abusive visitors.

There are numerous opportunities available to the administrator of a watershed that permits selected activities. If body contact with the water is prohibited and the water purveyor can convince his superiors that full treatment is still necessary, he is assured on the latter half of his main objective — an adequate supply of pure water. Recre-

Figure 3.—Permission of access and selected activities on watersheds may result in an undue amount of vandalism, as evidenced by this badly mutilated tree.



ation seldom has an impact on the *adequacy* of a watershed's supply *(Gomez and Crane 1968)*. If some recreation is allowed, the water purveyor should obtain the resources to carry out a public-relations program that will explain how recreation can be made compatible with water supply. This might go a long way in relieving some of the problems cited previously.

As with the watershed on which all forms of recreation are permitted, the watershed on which selected activities are permitted will probably have a broad base of support for its total program. This support often comes from the recreating public rather than from a few concerned citizens. A public-relations program would be the logical way to develop the broad base of support.

If the water-supply supervisor can successfully integrate water supply and recreation objectives, he can be a top-level municipal administrator who will have the advantage of experience over most of the elected officials in the administration. This experience and wisdom will be called on in many decision-making situations. We aren't sure whether this should be classed as an opportunity or as a problem!

## CONCLUSIONS

Recreation may be common on many municipal watersheds by the year 2000. What forms of recreation and on which watersheds or reservoirs is hard to predict, but managers of municipal watersheds in the Northeast should be aware of the problems and opportunities that other managers have faced.

If a watershed has an open-door policy, the biggest problem the municipality may have to overcome is the increased burden that recreation puts on a fixed budget. The biggest problem the water-supply supervisor must overcome is to not allow his water-supply objectives to become diluted by recreation objectives. The main benefit that recreation on municipal watersheds offers is the opportunity to provide a needed community service in addition to water supply.

If the decision is made to forbid all forms of recreation, then the management team should be ready to defend this decision before interested citizen groups. The management team should capitalize on the opportunity to explain the contribution the watershed and reservoir make to the community.

The greatest problems for managers of watersheds where selected recreation activities are permitted are money and rule enforcement. If money is made available for full treatment, then recreation might be considered the catalyst for safe water in the community.

It would seem that managers of municipal watersheds would gain money, time, and effort by preparing a working plan of what their watersheds and reservoirs can handle in the way of recreation. Contingency plans for the three possible alternatives should be developed. For instance, can the watershed handle an open-door policy? What would that cost in terms of additional water treatment and more or higher paid personnel? How would recreation objectives be integrated with water-supply objectives? Are the two objectives possible on the watershed, and, if so, can they be compatible?

If a water-supply governing board decides on a closed-door policy, what steps should the management team be prepared to take? Where are you likely to find support or opposition to a closed-door policy? How much effort will be needed to maintain or even enforce the policy?

The water-supply superintendent of a watershed on which selected recreation activities are permitted should ask him-

self all the above questions, because he will be faced with all of the problems. Why can't his reservoir handle the impact of an open-door policy? How much should that door be opened — halfway? three-quarters of the way? or just enough to permit land-based recreation such as hiking or bird-watching at some distance from the shoreline?

We suggest that water-supply managers prepare themselves to answer these questions.

Contingency plans should also include estimates of what full-treatment costs are now and will be 5 or 10 years from now. In preparation of each plan, questions such as these should be considered:

1. What level of pollutants is introduced to a system of a given size if recreation activity A or B or C is permitted?
2. Are these levels additive when introduced in combination?
3. What levels of investment in treatment facilities would be required to permit various levels of pollutants to be introduced with no ill effect on water quality?
4. Would the community pay for recreation on their watershed? Would the community pay for the additional treatment that would be required? Costs may include water color and taste as well as money.
5. Are there any alternatives to permitting recreation on a community's water-supply system? For example: construction of another reservoir for flood control and recreation *(Wilson 1966)?*

Answers to questions such as these, a knowledge of what the water-supply system can handle, and a more thorough understanding of the problems and opportunities of recreation on municipal watersheds will be needed by managers between now and the year 2000.

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# SOIL CONSERVATION – A PARAMETER OF QUALITY WATER YIELDS

*by* DAVID K. BOWEN, *Soil Conservationist, Watershed Planning Division, Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C.*

*ABSTRACT.* Reviews (1) soil conservation methods used by landowners, (2) conservation objectives in small watershed projects, (3) conservation work in multicounty resource conservation and development projects, (4) the use of soil surveys as natural resource planning aids, and (5) a newly authorized system of land inventory and monitoring.

THE WORK of the Soil Conservation Service is of special importance to you who are concerned with managing municipal watersheds. Nearly two-thirds of America's land — even a higher percentage in the Northeast — is privately owned. How carefully this private land is used — how sediment from this land can be kept out of streams, bays, and reservoirs — is of extreme importance to municipal watershed managers. And SCS provides a nationally coordinated effort to control erosion and sedimentation on private land.

A brief history of the soil conservation movement may be helpful before discussing program, progress, and prospect.

It was in August 1933, during the depression and in the midst of the great drought, that this Nation initiated a program of soil conservation and erosion control. The Soil Conservation Act, enacted in April 1935 and later amended, established the Soil Conservation Service in the Department of Agriculture, with authority to provide technical assistance, soil surveys, and other activities *(SCS 1973)*.

A model soil conservation district law was distributed in draft form to the states in May 1936. The states were asked to enact the model law, permitting the creation of individual soil conservation districts. A district would have the power to develop a comprehensive erosion-control program and formulate tentative regulations governing land use. The struggle within the bureaucracy, the political climates within the states, the conservative orientation of farm leaders, and other circumstances constrained the early role of soil conservation districts *(Morgan 1965)*. They chose to work with individual farmers to plan and apply conservation practices.

Now, some 37 years later, soil conservation districts blanket nearly the entire Nation. The Soil Conservation Service — which has about 13,000 employees

providing assistance in nearly 3,000 counties — has been given increasing authority and responsibility. Here are examples of work by the Soil Conservation Service *(USDA 1972)*.

1. More than a million farmers or other landowners received technical help from SCS in 1972.
2. More than 26,000 agencies of state and local governments received assistance in 1972.
3. Assistance under the Small Watershed Program included completion of 29 projects, engineering on 11 more, starting construction on 41 projects, starting planning on 28 projects — a total of more than 1,000 projects in some stage of planning or construction.
4. The Great Plains Conservation Program, which covers parts of ten western states, has provided conservation contracts with about 42,000 farmers, covering more than 77 million acres.
5. Plant Material Centers released or registered six new plants for soil conservation use during 1972.
6. More than 42 million acres of land were soil-surveyed in 1972. A cumulative total of 40 percent of the entire nation has been surveyed.
7. Twenty-five new multicounty Resource Conservation and Development projects were authorized in 1972, making a total of 123 projects.

## CHANGING TIMES

Questions began to develop about the earlier decision of soil conservation districts and the Soil Conservation Service to work almost exclusively with farmers to preserve and build basic productivity into the soil *(Held and Clawson 1965)*.

Economic growth, technological advance, and — most important — the automobile started a migration from the farms to cities and, later in the 1950s and 1960s, to the suburbs *(U.S. Census Bureau 1970)*. Construction activity laid bare more than 1 million acres of land each year for long periods of time, causing dramatic erosion and subsequent sediment damage *(Berg 1973)*.

The nation's number one pollutant, by volume and weight, is sediment. About half of it comes from cropland erosion; the other half comes from highways, streambanks, public lands, and suburban development.

The principal way that pesticides, plant nutrients, and infectious organisms leave the land and enter water bodies is by attachment to soil particles. Rough estimates of the suspended solid loading that reaches the Nation's streams from surface runoff shows these to be at least 700 times the loading caused by sewage discharge *(SCS 1972)*.

Sediment yield from areas under construction activities are 10 to 2,000 times that of agricultural or forested areas *(USDA 1969)*. After development, the increased runoff places additional burden on the drainage system, causing unprotected channels to become unstable; and erosion and sediment damage result.

Our study of the rate of silting of Lake Barcroft in Fairfax County, Virginia, showed that the watershed sediment yield from 1938 through 1957 was more than double that from 1915 through 1937. The increase was due mainly to areas left unprotected during construction. In 1957, two-thirds of the 15-square-mile watershed behind the Lake Barcroft Dam was urban, compared with the predominantly rural situation 20 years earlier *(Holeman and Geiger 1959)*.

In 1967, the Wisconsin chapter of the Soil Conservation Society of America began a survey of roadside erosion in Wisconsin. The study showed that secondary roads accounted for 97 percent of all roadside erosion. Stabilization of

state roads generally rated excellent; they accounted for the other 3 percent *(Briggs 1970)*.

It is estimated that there are 549,000 miles of streambanks in the United States that are subject to erosion. The more severe erosion on 148,000 miles of streambank is causing about 90 million dollars of damages each year *(Committee on Public Works 1969)*.

Public land in the eastern United States is not considered a major erosion source or major contribution of sediment.

The future outlook is not good. Between now and the year 2000, we expect that building in and around the metropolitan areas will be equivalent to everything built in the 350 years since the English started colonizing North America *(Berg 1973)*. Because of general ignorance of the land's capabilities, we as a nation are on the path to untold damage from sediment. The costly and ugly misuse of the land is distressing to more and more Americans. People are demanding legal action to control erosion and sedimentation.

## STATE ACTIONS

Maryland was the first state to pass a statewide sediment-control program. The 1970 law requires that proposed earth changes be submitted to and approved by the appropriate soil conservation district. The counties and cities cannot issue a grading and building permit until the developer submits a grading and sediment-control plan approved by the appropriate soil conservation district and certifies that all work will be done pursuant to the plan. The counties and cities are given the enforcement responsibility *(Bowen 1972)*.

Virginia has passed erosion and sediment-control legislation requiring adoption of standards and guidelines by the State Soil and Water Conservation Commission. Conservation district programs must be consistent with the guidelines *(SCS 1973)*.

The Iowa Conservation District Law, enacted in 1971, (1) created six conservancy districts, covering the entire state; (2) declared erosion a public nuisance if it results in sediment damage to the property of others; and (3) charged soil conservation districts with setting soil loss-limit regulations, along with receiving and acting upon landowners' complaints of sediment damage *(Cox 1972)*.

A 1971 amendment to the Soil and Water Conservation Law of Illinois required that copies of proposals for variances to existing ordinances or for subdividing vacant or agricultural land be provided to soil and water conservation districts. The district has 30 days to submit a written opinion on the proposal *(Silliman 1972)*.

Pennsylvania has established an Environmental Quality Board with responsibility for developing and implementing regulations for erosion and sediment control. The aim of a September 1972 regulation is to control accelerated erosion from land-disturbing activities. Erosion and sediment-control plans must be prepared by persons trained and experienced in the field. Guidelines, standards, and specifications have been provided by some soil conservation districts *(Sediment Committee 1972)*. Others are expected to follow. The regulations include farmland and require erosion and sediment-control plans for all tilled land by 1 July, 1977.

The achievement of soil conservation districts and the technical quality Soil Conservation Service assistance is recognized. The National Association of Conservation Districts and the Council of State Governments are recommending a model state act for soil-erosion and sediment control. The model act would amend the state soil conservation districts law and would involve the state

soil conservation commissions and soil conservation districts.

The National Symposium on State Environmental Legislation held in Washington, D.C., in March 1972, adopted resolutions (1) supporting the placing of the responsibility for an erosion and sediment-control regulation program with conservation districts, and (2) suggesting that state sediment-control legislation should be in the form of amendments to existing enabling conservation district law.

## LOOKING AHEAD

The Soil Conservation Service has developed a long-range plan to guide future efforts. In it, we focus on the task needed to improve and maintain resource-management systems so that they meet quality standards for current and long-term use. Along with other goals, the plan calls for broadening our activities in land inventory and monitoring *(SCS 1971)*. The Rural Development Act of 1972 provided authority, under Section 302, for land-inventorying and monitoring activities.

In 1958 and again in 1967, the SCS, along with other agencies, conducted conservation-needs inventories on private land, state and local government land, federally owned cropland, and Indian land. Data on soils, land use, and conservation treatment were collected from about 170,000 statistically located random sample areas averaging about 170 acres each and covering nearly 29 million acres. These data were expanded to provide estimates for 1.4 billion acres of land.

Plans are to obtain data for the remaining 0.9 billion acres of federal and urban land. In addition, the basic data for all land will embrace other resource uses that decision-makers need to know about for planning the use of the nation's soil, water, and related resources.

Our studies show a need for knowing the location of prime farmland, wetland, flood plains, and critical eroding land, and for locating potential impoundment sites.

The question of where these are to be located can be answered by overlaying basic resource elements like soils, plant cover, land use, flood frequency, and topography. The collection and overlaying of these data will be done manually at the start. However, a program is proposed to include automatic storing, retrieving, and displaying of the results. We envision that a national report of the changing quality of resources will be issued at 5-year intervals; the first report is due in 1979. County, state, and regional reports on inventoried items or resource elements are expected at more frequent intervals. Of course, the data will be made available as collected.

In summary:

1. The control of erosion and sediment on private land is important to municipal watershed managers.
2. The work of the soil conservation districts and the Soil Conservation Service in controlling agricultural erosion and sediment is well recognized.
3. New state laws are requiring all land users to exercise greater control over erosion and sedimentation.
4. Conservation districts with SCS technical help are being given an important role under these new laws.
5. The National Association of Conservation Districts and the Council of State Governments are recommending a model state act for controlling erosion and sediment.
6. In a new program of land inventory and monitoring, under authority of the Rural Development Act of 1972, SCS envisions an expansion of collection of data on the condition of land and water resources.

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# USE OF HERBICIDES IN TIMBER – AND RESERVOIR – MANAGEMENT PROGRAMS

*by* ROY R. JOHNSON, *Associate National Program Director, Industrial Herbicides, Amchem Products Inc., Ambler, Pennsylvania.*

*ABSTRACT.* Herbicides *can* be used in timber- and reservoir-management programs. Knowledge of herbicides, application methods, timing, and nature of the area to be managed will enable the land manager to control and manage watershed vegetation with minimum contamination of water and minimum impact on the environment.

A LIMITED NUMBER of herbicides are registered for use on stream banks and around lakes, ponds, and streams. Other herbicides may be used in watershed areas for vegetation control and timber management if a suitable buffer strip is left between the treated area and the stream bank. The application of herbicides today is governed by label uses and restrictions, which are printed on the herbicide product label. Since most land is a watershed of some sort, there is room for some common sense in the interpretation of herbicide uses.

To help us make more enlightened choices on the use of a particular herbicide for a particular watershed use, I will first discuss methods of applying herbicides and their rates of disappearance, which are usually governed by the methods of dispersal or decomposition.

## NO TWO ALIKE

At the outset we should be aware that no two herbicides are identical, and no two formulations are exactly identical. The physical and chemical characteristics of each specific herbicide will help us to determine where each may be used safely in a watershed environment with a minimum chance of environmental contamination.

The herbicides 2,4-D, diclorprop, 2,4,5-T, and silvex are in a group of herbicides called the phenoxyacetic acids, also called phenoxies. In general, they have a short persistence in the soil. The phenoxy herbicides are usually applied to the foliage or stems of woody plants and certain annual and perennial broadleaf species. They have little or no activity in the soil.

Two other herbicides — dicamba and picloram — have longer persistence in

the soil and may be applied to the foliage, stems, or soil to control woody plants. Other herbicides such as MSMA or TBA may be used in combination with the phenoxy herbicides for improved control of certain woody species. Dicamba and picloram are also usually applied in combination with a phenoxy herbicide. Bromacil, fenuron, and karbutilate are active through the soil only and are commonly applied as granular or pelleted treatments.

Laboratory studies by Altom and Stritzke on a forest soil from the Ouachita Highlands near Lamar, Oklahoma, indicated that the soil half-lives of four phenoxy herbicides, dicamba, and picloram were: 2,4-D, 5 days, dichlorprop, 12 days; 2,4,5-T, 24 days; silvex, 21 days; dicamba, 32 days; and picloram, greater than 100 days. Half-life on a grassland soil from the same location was shorter for each herbicide.

## PRECAUTIONS NEEDED

When a herbicide is applied to a watershed area, precautions are normally taken to prevent it from getting into the runoff water. Herbicides can find their way into runoff water by airborne drift, surface runoff, or movement in the ground water. Drift is the physical movement of spray particles at the time of application. The particles are moved with the current of air into the adjacent bodies of water.

With certain herbicides there is also a possibility of herbicide contamination by volatilization or by wind erosion, but these are minor sources. Herbicide contamination by surface runoff refers to the movement of herbicides with suspended soil particles or on surface litter or by being dissolved or emulsified with actual surface runoff waters. When herbicides on the soil surface are leached into the ground, they may eventually reach the ground water. Loss of herbicides by leaching will vary with the solubility of the particular herbicide and also the degree of adsorption on the soil. In addition to the nature of the herbicide itself, the nature of the surface litter, soil texture, and other factors will also affect the likelihood of groundwater contamination by herbicides.

The amount of herbicide available for contamination of the aquifer will of course be determined first of all by the total amount of herbicide applied per unit of surface area. Application techniques in which lower total amounts of herbicides are applied will offer less opportunity for contamination. In general, individual-stem applications such as basal sprays, tree injections, or spot sprays will apply less herbicide than broadcast or blanket sprays.

Another characteristic of herbicide sprays that may help to determine the contamination potential would be formulation. For example, the phenoxy herbicides may be formulated as esters, emulsifiable acids, oil-soluble amines, water-soluble amines, or water-soluble salts. The type of formulation used will be determined to a great degree by the method of application used. However, there is less contamination potential from certain formulations than from others. The phenoxy herbicides are generally synthesized as acids, which are usually dry crystaline solids. The acid itself may be dissolved in a suitable solvent, which may then be emulsified in water and used as a foliage spray or basal spray.

The acid may be combined with an amine. The resulting amine salt of a phenoxy acid is soluble in water. These water-soluble salts may be applied in water as foliage sprays or injected into the stem of the woody plant. A phenoxy acid may be reacted with an alcohol molecule to make an ester. Esters may be emulsified and used as foliage spray

or may be diluted in oil and applied as basal sprays or injected into woody plant stems. Phenoxy esters may be classified as volatile or low-volatile, depending on the alcohol used in esterification.

Oil-soluble amines are a recent development in phenoxy formulation. They are made by combining certain non-water-soluble amine salts with a phenoxy acid. The resulting oil-soluble amine may be emulsified and applied as a foliage spray or used as a basal spray or injected into the woody plant stem. Since oil-soluble amines are not volatile, they combine the activity of an ester with the non-volatility of an amine salt. This reduces the possibility of environmental contamination by volatilization.

When using any herbicide near water, the most effective way to reduce or eliminate water contamination is to avoid direct application to the water surface. Studies by Norris indicate that this is the source of most water contamination by herbicides.

## TECHNIQUES

Injection of herbicides with a tree injector or hatchet applicator uses little herbicide and gives almost no opportunity for stream contamination, even when used near a body of water. Basal sprays of dicamba, picloram, a phenoxy herbicide, or a combination of these in an oil carrier to the lower 18 to 24 inches of brush to be controlled are also very free of contamination potential. The backpack mistblower basal, which has recently been developed, does give more opportunity for droplets to escape the site of application, so a reasonable buffer strip should be left near water. Ground foliage sprays and aerial sprays require wider buffer strips between the application and the water's edge. Width of this strip will vary with wind direction, spray technique, and foliage density. Reasonable specifications should be developed for various spray techniques by the land manager.

Drift control agents, such as inverts, foams, thickeners, and the new polymers should be used with properly designed equipment to increase droplet size of herbicide sprays and improve targeting of spray applications. Pelleted herbicides do not drift, but may contaminate in areas with a high water table or when used on steep slopes adjacent to streams or reservoirs.

Norris made the following observations for the land manager concerned with the planning and use of herbicides:

1. Herbicides can be used safely in the forest in most instances.
2. Avoid the treatment of areas which have a high water table.
3. When operating in areas which are particularly sensitive from a biologic or public relations standpoint, stream contamination can be held to an absolute minimum by recognizing and avoiding those situations which lead to direct application to streams or surface water.

Herbicides *can* be used in timber- and reservoir-management programs. Knowledge of application methods, herbicides, timing, and nature of the area to be managed will enable the land manager to control and manage watershed vegetation with minimum contamination of water and minimum impact on the environment.

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# MULTIPLE USE ON MUNICIPAL WATERSHEDS? ONE WAY TO FIND AN ANSWER

*by* DAVID P. WORLEY, *Project Leader in Economics of Timber Growing, USDA Forest Service, Northeastern Forest Experiment Station, Columbus, Ohio.*

*ABSTRACT.* A sampling of the pressures for various multiple-use activities shows the complex situations created by multiple-use management, the concerns that municipal watershed managers should have, and the importance of preplanning, with particular reference to facilities shared by all the uses eventually selected as the watershed's multiple-use package. A five-step approach is described and illustrated by example for selecting multiple-use activities to feature and for adjusting a package of activities to match the funds available for shared facilities.

THE YAHOO Municipal Water Company owns most of its watershed and has locked it up for many years. Willy Watershedmanager checks the gates to the fire road frequently and renews the NO TRESPASSING signs whenever they are torn off or rotted in place. Willy is well satisfied with conditions as they are. The water quantity and quality he delivers from company reservoirs are both satisfactory. The board of directors is happy, and his pay check, although too small, is adequate and regular and on time.

Ophelia Outdoorsportenthusiast parked her pickup truck at one end of a bridge that spans a company reservoir and walked onto the bridge to look at the water. She noticed bass rolling to the surface after flies and wondered what harm a little fly fishing would do. Her husband made an issue of fishing in the Yahoo Municipal Water Company reservoir at the next Isaak Walton Club meeting. Her daughter Cathy pictured herself waterskiing under the bridge, waving to her boyfriend on the bridge, who was intently watching her every graceful move. Cathy talked about waterskiing at the Girls' Athletic Association meeting in high school.

Billy Boyscoutleader wandered onto company land between a couple of missing signs and walked down to an oak grove near the water's edge. What an ideal spot for an overnight scout camp! A good place to put in canoes too, he thought. He raised the question at the next district scout meeting.

Annie Ardentbirdwatcher trespassed onto company land at the same place and saw a pileated woodpecker and a snowy owl; both were the first she had seen in years. She reflected that a few nature trails on the watershed would enhance the community. She suggested

the desirability of such trails at the next Birdwatcher's Club meeting and at the Flower and Garden Club meeting, as well.

Sam Squirrelhunter entered company land via a steep narrow valley where he couldn't see the NO TRESPASSING signs. He found some turkey scratchings and active squirrel-den trees where the oaks and hickories merged into the beech and maple. Why is this area closed to hunting?, he thought. He asked this question at the Sportsman's Club meeting later in the week.

Fred Furnituremanufacturer, who was with Sam, didn't say a thing, but duly noted the big maples and black cherry in the upper hollows. He waited to talk about these trees to Shorty Sawmiller over lunch the next day.

As far as the Yahoo Water Company and Willy Watershedmanager are concerned, the fat's in the fire. Multiple use has caught up with him and his watershed. Sooner or later one or more of these demands are going to hit the stodgy old water company like an avalanche. Eventually, either the Yahoo Municipal Water Company is going to plan for these kinds of policy changes and move successfully when the demands become evident, or the company may be forced to move precipitously and maybe disastrously if they wait till the demand overwhelms their ability to resist. Water companies must expect social pressures to demand much less limited use of their watershed properties.

## MULTIPLE-USE CONCERNS OF WATERSHED MANAGERS

Ordinarily the watershed manager's primary goal is to deliver predictable quantities of water to meet specific quality standards for urban communities. When this isn't done, the rest of the water company's operations become difficult. Often the manager can't do much about water quantity except to predict how much is likely to be available and to keep a record of water stocks on hand. On the other hand, the standard procedure for dealing with water quality has often been to keep human activity on the watershed to a minimum. Furthermore, additional uses of the watershed introduce risks and uncertainties that challenges the manager's primary responsibility.

Other presentations at this symposium and in watershed-management literature tell us that on a finite watershed, water quantity and temporal distribution are altered significantly only by large-scale and drastic manipulation of vegetation. Such vegetation changes are unlikely to occur on municipal watersheds in the Northeast as a result of the kinds of outside use pressures already described. They can be expected only from a deliberate attempt to increase water yields.

We also know that water quality is subject to deterioration by human activity and by the facilities required to serve the people for the variety of uses being considered. Probably the most important facility is roads for access appropriate to the various uses.

Roads for access need to be planned for all possible uses at the outset so as to be part of the whole multiple-use watershed-management system. Parts of the whole system needed for a particular use can be implemented when the demand for that use becomes great enough to justify its implementation. Failure to do this overall planning job in the first place may result in inordinately high costs and increased water-quality risks brought about by creating redundant facilities. A road system, for example, may be designed to provide access for several uses on a shared basis if prior planning is done carefully. In the absence of such planning, a separate access road may be needed for each use. The

lack of planning in this case would increase the mileage of road, thereby increasing risks to water quality and increasing road costs. Long-range planning is the answer to these problems.

When confronted with other uses on the municipal watershed, the water company and the watershed manager have justifiable apprehensions about their ability to manage for these foreign uses. How many people can I have on a nature trail at one time, and how do I control them? Is there really enough wildlife-habitat potential on the watershed to justify habitat management and hunting? Will the potential income from the timber be worth the time and trouble to manage for timber production? Will the net returns from timber be large enough to really mean anything to the water company income statement and balance sheet? Should we open up this multiple-use can of worms for good will, or as protection from or control of the inevitable? What might we expect in the way of capital costs and management expenditures? What chance do we have of recovering money outlays? If multiple use is going to be expensive, who will pay? Is it cheaper to stand and fight the enforcement and legal battles to keep the status quo, or to plan and implement multiple use?

## AN APPROACH FOR DECIDING ABOUT MULTIPLE USE

The demands and problems surfaced here pinpoint a clear need to develop the kinds and mixes of multiple uses appropriate to a particular municipal watershed in a direct and systematic manner. Five procedural steps will be discussed which are designed as a planning framework for executives to use (1) to decide if multiple use is viable, and if so, (2) to channel resources to those uses that offer a worthwhile potential, (fig. 1).

### *Define and Describe Each Activity*

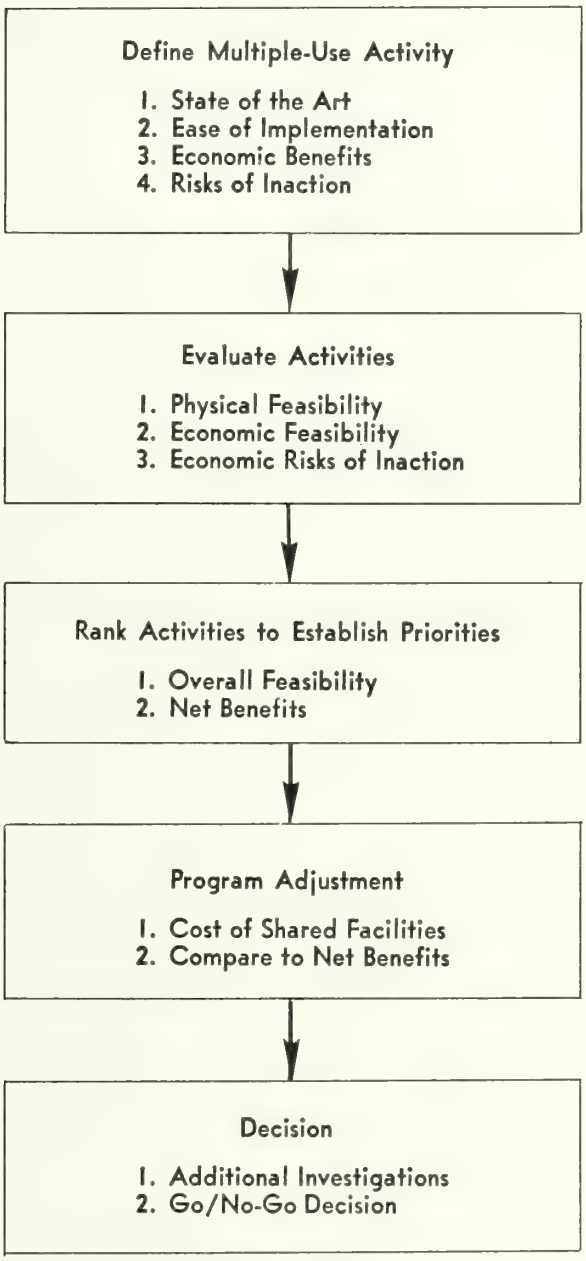
The first step is to describe each multiple-use activity as a discrete package. A description statement includes a name for the activity followed by a description that should answer the relevant who, what, when, why, and where questions. Then estimates of feasibility elements for the activity that will be used in evaluation are posted. Table 1 shows a format for displaying this information. The timber-management sample featured will be followed through the whole procedure.

An assessment of *state of the art* requires judgments about the technical problems that may be encountered, as well as the availability of technical skills and the market context in which this multiple use will have to operate successfully. In this case, state of the art was judged high because ample research and precedent indicate that such a program can be undertaken without jeopardizing watershed objectives, is within the state of the art, and that arrangements can be made readily for technical help and markets.

*Ease of implementation* requires a certain amount of introspection. How much trouble will our company have getting there from here? Compatibility with existing philosophies and procedures is important, together with the amount of effort to do an effective job and its appropriateness as to use of company land. Our example contains a low rating for ease of implementation mainly because this will be a radical departure in historical patterns and operating philosophy.

*Economic benefits* must be estimated according to company planning criteria. The suggestion in our example is that identifiable benefits be estimated for a 10-year period and discounted to the present at 6 percent. As part of the economic-benefit analysis, costs are dis-

Figure 1.—Steps for deciding about multiple use.




The system illustrated in figure 1 was adapted and expanded from an article by Logan M. Cheek. (Cost effectiveness comes to the personnel function. Harvard Bus. Rev. 51 [3] : 96-105. 1973.)

**Table 1.—Multiple-use activity description**

Multiple use name: Timber management

Description: Manage timber to promote timber production and other uses on the 10,000 acres of the watershed away from hazard areas. Begin 1974 and continue.[1]

| Feasibility: | | | |
|---|---|---|---|
| State of art | (High) | Moderate | Low |
| Ease of implementing | High | Moderate | (Low) |
| Economic benefits | (High) | Moderate | Low |

| Identifiable benefits | Potential impact | Probability of occurrence | Probable impact | Probable net benefits[3] |
|---|---|---|---|---|
| 1. Potential timber returns[2] | $40,000/yr. | 0.80 | $32,000/yr. | $235,000 |
| Total | | | | $235,000 |
| Identifiable costs | | | | |
| 1. Timber mgt. costs[4] | $10,000/yr. | 1.00 | $10,000/yr. | $ 73,600 |
| 2. Water quality monitor[5] | 5,000/yr. | 0.50 | $ 2,500/yr. | 18,400 |
| Total | | | | $ 92,000 |
| Probable present net benefits | B/C ratio 2.5 | | | Net $143,000 |

Intangible benefits: 1. possible minor increase in water yield.
2. possible reduced chance of catastrophe, i.e. fire, insects, diseases.
3. possible increase in vegetation management flexibility for future.[6]

Economic risks of not acting: (High) Moderate Low
Tree cutting and planting necessary for any other use. Probability of sustaining other uses without a systematic timber overstory management program is low.

Assumptions: Make assumptions, sideboards, calculations explicit.
[1]200 feet from lakes and stream channels to minimize water quality hazards.
[2]Timber returns abstracted from research literature and precedents on other lands. Variety of local markets exist. Amount of returns depends on careful marketing.
[3]6% discounted costs and values for 10 year period.
[4]Based on engaging forestry agent for planning and implementing.
[5]Expect to monitor water quality till timber management side effects are known then to record quality for other departments.
[6]Research results in other fields suggest these are possible but they aren't quantified or altogether firm.

counted in a similar fashion. Allowances are made for probability of occurrence. In the example, some of the land might be located so that the potential impact might not be realized. Water-quality monitoring costs might not need to be incurred over the whole period at the intensity suggested, but engaging a forestry agent is a 100-percent requirement. Identifiable benefits and costs are treated to produce a benefit/cost ratio and an estimate of present net value. The magnitude of the latter is a basis for estimating economic benefits and judging the desirability of spending money for this activity.

A place is left on this form for re cording intangible benefits. This is in tended to give the executive a feel fo the qualitative side effects of a favor able decision. Whether this statemen becomes any more than rhetoric depend upon both the care with which it is re corded and the attention the executiv pays to such items. These two attitude are likely to go hand in hand. Later o we will make more use of the intangible benefit item. The intangible-benefi statement is not intended to be a spring board for the last evaluated item, *Risk of inaction,* which needs to stand b itself.

The point made in our example about risks of inaction is that only through a systematic program of timber overstory management can we expect to sustain the vegetation requirements for a variety of uses. The risk of not acting in this regard was rated high.

Finally, there is a section on the form called *Assumptions*. It is included for making explicit the key assumptions that underlie the description. Though it is filled out in abbreviated fashion in table 1, the abbreviations point to the intent. Without careful and explicit treatment of the assumptions, the description elements become mere assertions. But when filled out appropriately, assumptions indicate to the executive the length of thought given to each consideration. An executive can decide if the presented depth of thought is adequate for the particular planning stage for which the form was submitted.

Our example is brief; the assumptions are general. Such depth may be appropriate at an early stage of planning, but certainly not at a stage of planning when final go/no-go decisions are imminent. It is envisioned that the system be implemented at each of the different stages of planning from a general initial proposal to the comprehensive background needed for the final decision. Table formats may be similar for all stages, the main difference between stages being the depth of information developed, which is described in the assumptions section.

Standards are needed to help guide the rating of these feasibility elements and as a focal point for assumptions relating to them. Though standards need to be written, they should be considered flexible guidelines to orient the thinking of the person actually making the appraisal and as a basis for feedback from those who actually make the decision. Table 2 presents a set of general guidelines or standards for rating the elements. Of course, every company has its own requirements, so it is hoped that the guidelines in table 2 will help individual companies draw up their own guidelines.

### *Evaluate Activities*

The second step is designed to form an estimate of how good a bet this particular activity is for the municipal water company. Table 3 shows that we draw heavily on the information developed in the first step and use it to judge (1) physical feasibility, (2) economic feasibility, and (3) the risks of inaction. The table is in the form of a decision table so that the activity can be characterized at each step as to whether it is an (1) excellent, (2) good, (3) fair, or (4) poor activity for the particular watershed.

Table 3 is structured so that it is tested for physical feasibility first. The results of this test enter into the test for economic feasibility etc. Activities judged poor at any stage of the process are withdrawn from further consideration. They won't disappear from sight because we will record them later to account for them.

It is clear from the table that it really takes a high-class proposal to have a final rating of *excellent*. Though the first feasibility test is a little generous with the excellent rating, by the time we get through the drill, everything has to be superior for a proposal to rate excellent. Conversely, combinations of moderate and low in the first feasibility test lead to many *fair* feasibility ratings, but only one *good* rating. By the time we complete the whole rating schedule, there are more *goods* occupying the body of the table than *fairs*.

As we trace our timber-management example through the form, we find that our two high ratings and one low rating from table 1 lead us to judge this as a good alternative, not an excellent one. If both the physical feasibility elements

Table 2.—Standards for multiple-use activity statement

| Descriptive grade | Feasibility | | Criteria | |
|---|---|---|---|---|
| | State of the art | Ease of implementation | Economic benefits | Economic risks |
| High | 1. Can be conducted without jeopardizing primary watershed objectives.<br>2. Appears simple.<br>3. Adequate research, precedent and/or arrangements make outcome highly probable.<br>4. Expertise available in-house or easily contracted.<br>5. Market (demand) appropriate to potential scale of supply.<br>6. New technology not likely to render obsolete in near future. | 1. Little or no extra effort required.<br>2. Compatible with existing in-house equipment procedures and operating philosophy.<br>3. An in-house cost competitive job is feasible.<br>4. Annual maintenance procedures likely small and to come at a convenient time.<br>5. Spatial efficiency easy to achieve. | 1. Present net estimated benefits over . . . . year period at . . . percent exceed $. . . . . | 1. Political risks of inaction likely to be costly.<br>2. Physical risks of inaction likely to alter costs of fulfilling water quantity and/or quality.<br>3. High costs of outside alternatives to achieve demands. |
| Moderate | 1. Minor risks of compromising watershed objectives involved but can be overcome easily.<br>2. Appears complex but can be visualized to conclusion.<br>3. Some research or precedent or arrangements make predicted outcome credible.<br>4. Specialists required are available.<br>5. Market relations unclear, perhaps difficult to control.<br>6. Changing technology unlikely to make investment obsolete but may affect operations. | 1. A modest new effort will be required.<br>2. Some operating changes foreseen, but not disruptive in nature.<br>3. Getting a cost-competitive job likely to be possible with present contacts.<br>4. Annual maintenance and management procedures may require extra effort but not a serious inconvenience. | 1. Present net estimated benefits over . . . . years at . . . . percent between $ . . . . . and $. . . . . | 1. Political, physical, or economic risks of inaction present but not imminent or substantial.<br>2. Other outside alternatives to achieve needs available at comparable cost. |

| | | | | |
|---|---|---|---|---|
| Low | 1. Major risks to watershed objectives envisioned, which may be difficult to correct.<br>2. Appears complex; unfamiliar effort involved.<br>3. Little to go on, so low probability that outcome as predicted.<br>4. Competent technical advice scarce and expensive.<br>5. Scale of potential supply too large or too small for market, with attendant problems.<br>6. New technology likely to require major changes in current feasible efforts. | 1. Substantial new procedures required.<br>2. Radical departures from historical practices require major changes in equipment, procedures, or operating philosophy.<br>3. Outside contracts required to get cost-competitive job are difficult to negotiate.<br>4. Annual maintenance procedures likely to be source of considerable inconvenience.<br>5. Spatially possible but inefficient. | 1. Present net estimated benefits over .... years at .... percent less than $..... | 1. Political, economic, or physical risks of inaction inconsequential.<br>2. Other outside alternatives to satisfy demands available at lower cost. |

Table 3.—Multiple-use activity evaluation form

Alternative name: Timber management
Description summary:

| | |
|---|---|
| State of art | high |
| Ease of implementing | low |
| Economic benefits | high |
| Economic risks | high |

1. PHYSICAL FEASIBILITY

| State of art | Ease of implementation: High | Moderate | Low |
|---|---|---|---|
| High | Excellent | Excellent | (Fair) |
| Moderate | Excellent | Good | Fair |
| Low | Fair | Fair | Poor |

2. ECONOMIC FEASIBILITY

| Physical feasibility | Probable net economic benefits: High | Moderate | Low |
|---|---|---|---|
| Excellent | Excellent | Good | Fair |
| Good | Excellent | Good | Fair |
| Fair | (Fair) | Fair | Poor |

3. ECONOMIC RISKS OF INACTION

| Economic feasibility | Economic risks of inaction: High | Moderate | Low |
|---|---|---|---|
| Excellent | Excellent | Good | Good |
| Good | Good | Good | Fair |
| Fair | (Good) | Fair | Poor |

4. OTHER NOTES BROUGHT FORWARD

Net economic benefit—dollars $143,000
Economic risks. Other uses require systematic timber mgt. to be effectively sustained.
Benefit-cost ratio 2.5

had been rated low, our rating at that stage would have been poor and we would go no farther in our rating.

The importance of doing an effective, objective, and thorough job at each step is becoming apparent at this early stage. Each step builds on the previous step, and any errors are compounded as we go along. It is becoming apparent too that each watershed will have a tailor-made evaluation for each activity. An activity that might rate excellent on some watersheds may fall out of serious contention on others.

Finally, other items are brought forward from the first form for later use in ranking the activities.

### *Rank the Activities*

After each activity has been evaluated on its own merits, it needs to be classified with others to generate alternative multiple-use packages. A convenient way of doing this is shown in table 4. First the activities are ranked according to their overall feasibility. The net benefits and benefit-cost ratios are posted, and priorities are assigned. In our example the priorities don't exactly follow the feasibility ratings. Potential net benefits influence the priorities. Here, for example, if the water company wants to generate any land-based multiple-use program, it must recognize timber management early in the game because it

Table 4.—Multiple-use activities ranked for program development

| Alternative ranking; overall feasibility | $ Net benefits | Benefit-cost ratio | Priority |
|---|---|---|---|
| Excellent | | | |
| Fishing and boating | 25,000 | 1.3 | 1 |
| Organization camping and picnicking | 7,300 | 1.1 | 3 |
| Good | | | |
| Timber management | 110,000[1] | 2.1 | 2 |
| Public camp and picnic area | (15,000)[2] | — | 4 |
| Fair | | | |
| Wildlife management and hunting | 34,000 | 3.2 | 5 |
| Nature trails | 1,100 | 1.1 | 6 |
| Poor | | | |
| Public trail camp | (500) | — | 7 |
| Total | 161,900 | | |

[1]Requirements for wildlife management and nature trails induce timber opportunity costs of $33,000 which is accounted for here. For packages not using these activities net benefits are $143,000 and the benefit/cost is 2.5.
[2]Benefits in brackets are negative.

will provide a dollar base for shared facilities. Those activities ranked poor in feasibility are shown. They can be included if the intangible benefits or the risks of inaction are high enough and if the package net benefits are large enough to afford them.

Conversely, if the water company is in an austerity period, or if budget limits the package, other additional activities can be cut. The activity ranking becomes the basis for allocating resources. For example, here we have estimated the lowest net benefits to accrue from a package of these multiple uses. By cutting negative benefit activities we could generate a highest figure of $177,500. Other combinations could be evaluated for potential net benefits as well. This information becomes a basis for adjusting the multiple-use program so that a match can be achieved with the costs of shared facilities.

### *Adjust the Program to Fit*

In this step we seek to match the estimated net benefits with the costs of shared facilities. For our purposes, only access costs will be considered, and it is assumed that all other costs have been figured into the net benefits for each activity. Access requirements involve a permanent road network connecting the various activity sites. Entrance provisions are needed for some activities such as camping and picnicking. Area is needed for dispersed activities such as timber and wildlife management.

For the 20,000-acre example area, these may be specified as in table 5. The cost calculations in table 5 proceed in a straightforward manner from left to right. Costs of the special facilities that depend on the road network for the package can be plowed back into the activity costs if this is likely to cause a change in the multiple-use package. A new net benefit and benefit-cost ratio can be calculated, resulting in a new estimate of total net benefits to be matched with only the permanent road-network costs.

The general costs used here may be appropriate in the early phases of deciding whether to go into certain uses

Table 5.—Costs of shared facilities

| Cost item | Multiple-use activity | Miles or units | Cost/unit[a] | Total cost |
|---|---|---|---|---|
| Permanent road network | All | 10 | $8,000 | $ 80,000 |
| Special roads and trails dependent on permanent road network | Fishing and boating entrance | 0.2 | 8,000 | 1,600 |
| | Timber-management truck trails | 3 | 2,000 | 6,000 |
| | skid trails | 6 | 1,000 | 6,000 |
| | loading areas | 3 | 500 | 1,500 |
| | Organization camp entrance | 0.5 | 8,000 | 4,000 |
| | Public camp entrance | 0.8 | 8,000 | 6,400 |
| Total estimated construction costs | | — | — | 105,500 |
| Road location and engineering planning @ 15% | | — | — | 15,825 |
| Total | | — | — | $121,325 |

[a]Includes discounted allowances for maintenance for a decade.

at all. If a decision is made to investigate in more detail, then engineering planning costs must be undertaken to get a better construction-cost figure. This parallels the philosophy used in activity specification that, when the actual investment decision is close, sound technical information is required to zero in on the problems encountered. Planning costs enter into the total here as they did in the timber-management example.

### *Decision*

Will the water company spend $120,000 for an estimated $160,000 of present net benefits? This depends largely on the company and whether it will accept a 1.33 benefit-cost ratio as an adequate margin for investment under these circumstances. An affirmative answer at the early stage of decision-making in our example will probably indicate management's willingness to make the next planning investment to tighten up the information in the system so top management feels they are on firm ground rather than in dreamville. A succession of these rounds will eventually lead to a decision one way or another. In the meantime the watershed manager and executive management have a common ground for communication. The system may need to be altered in the consecutive rounds of investigation so that the executives have the specific local information they need and can feed back in a fashion that reflects their concerns about the place of watershed management in the total enterprise.

## CONCLUSION

Multiple-use management is inevitable on many of our municipal watersheds in the Northeast. At first glance it seems incredibly complex to a watershed manager who is used to managing for a single use. But these complexities fall apart when the multiple uses are subjected one by one to a systematic evaluation and recommendation. The one described here is one of many that can be found in textbooks on decision theory. Any general system found in textbooks or articles needs to be adapted to fit the problem and local circumstances as Logan M. Cheek's system used here was adapted and expanded from his original. It is hoped that this acts as a point of departure for your own search for and recognition of a systematic approach to multiple use on municipal watersheds.

# STATE TECHNICAL ASSISTANCE PROGRAMS

*by* ALFRED DARRACH, *Hydrologist, Northeastern Area, State and Private Forestry, U.S. Forest Service, Upper Darby, Pennsylvania.*

*ABSTRACT.* Discussions with representatives of the 12 Northeastern States showed that each State provides some technical assistance for municipal watershed management. The State Forester supplies technical help on forested land. Other State agencies concentrate on public health, fish and wildlife, ground water, and law enforcement. It was also found that few State Foresters feel that an intensive municipal watershed program is needed. The present response-type program now used by most State Foresters to assist municipal watershed management seems destined to continue at present levels, unless more funds are made available for an intensified effort. Few States are attempting to handle municipal watershed problems beyond the limits of the municipal watershed ownership. Almost none of the States have set up goals and their corresponding objectives for a municipal watershed program.

IN THIS SYMPOSIUM we have made an effort to identify the elements of management that affect water quality. In addition, we have explored current practices and operational procedures presently in use on municipal watersheds. Various management considerations of potable water quality, recreation, herbicides, and multiple use on these ownerships have been reviewed. Now consider the help that is provided to municipal watershed managers through state technical assistance programs.

## STATE FORESTERS INTERVIEWED

I consulted with the offices of 12 state foresters from Maine to Delaware and westward to West Virginia to evaluate these assistance programs. In the course of our discussions, several interesting facts came to light.

- All twelve states provide some technical assistance, usually for municipal watersheds that do not have the service of a forester.
- Considerable assistance is available to the municipal watersheds from state institutions other than the state forester. Much of this assistance, however, is not oriented to management of vegetation. The institutions most often mentioned were those that were concerned with public health, fish and wildlife, groundwater, geology, and enforcement of law.
- Of the state foresters interviewed, over 70 percent could not envision a need for an intensive municipal watershed program.
- There is a general intent to continue the type of service now offered. A more direct and specialized program

will not be undertaken by most state foresters.

Discussions about technical assistance yielded some general but useful bits of knowledge.

For instance, only 25 percent of the states considered that their technical assistance is specially geared to watershed needs. Generally the assistance given is of the CFM (Cooperative Forest Management) type, and only upon request. Ownerships visited were predominantly public, but some private property is serviced. Many types of help are provided, ranging from management plans to cruising and marketing forest products. In all cases, the blanket service of fire and insect and disease protection is available. Unfortunately, limited assistance or no assistance at all is offered in hydrology. The time allotted to each cooperator for services varies, but generally ranges from 2 to 5 days per year. The length of service time appears to be under re-evaluation in some states to spread the assistance available and still stay within increasingly limited budget and manpower constraints.

In a broader outlook, only one state mentioned giving special attention to watershed-management problems associated with private forest lands within the physical limits of a municipal watershed. More encouraging, 25 percent of the states have set or are setting goals for municipal watershed management. Fewer than 17 percent have set objectives for such a program. It was also found that about half of the states have lists of municipal watersheds; the remainder have partial information or none at all.

Two and possibly three states may expand their municipal watershed programs, but only on a request basis. If financial help, training, and technical assistance are provided by the state or federal government, increased management effort could be expected on municipal watersheds.

## DISCUSSION

At present, most of the technical assistance for municipal watersheds is provided to municipalities that are not able to provide this for themselves. The effort to date has been largely on a request basis and appears to be continuing on this basis. The assistance provided is really little more than general forest management with a watershed flavor. Possibly this is all that is needed today. Things could change, however, if increased use of these lands is wanted by the public. Better technology may become a necessity. There is little indication that the present general program will become specialized and aimed specifically at municipal watersheds, unless the public demands this service. In either the absence or presence of public demand, funds would be needed to expand and concentrate the technical-assistance.

A recent example of a state response to a municipal watershed need serves to emphasize what may be coming. Technical assistance given on the Thurmont Municipal Watershed, north of Frederick, Maryland, illustrates one type of service a state forester may be called upon to provide. In this case, a watershed specialist and the district forester worked together to produce a multiple-use management plan for the property and guidelines for intended logging.

Information about timber value, recreation potential, and water yield and quality was provided to the town fathers. Logging took place, and no lowering of water quality was experienced, even though the site of the timber sale was along the main watercourse and terminated within a few feet of the town's water intake. Great care was exercised during the operation to prevent erosion and sediment. In addition, trees were

left along the stream to shade the water and hold the banks. Finally, there was a return of $32,000 for the wood sold. This single sale paid half of the original cost of the entire property. Good technical advice and assistance from a qualified team provided by the state forester paid off for Thurmont, Md.

There are some elements of a municipal watershed program that appear to have been neglected by the state foresters. Two of the key items involved are goals and objectives. To date, few states have seen a need for these, probably because no real municipal watershed program exists. Much confusion and wasted effort associated with existing programs and municipal watershed assistance can be alleviated by setting program goals and objectives. Some of the advantages to setting these are a better apportionment of technically trained manpower to help reduce or remove existing workloads, and the coordination of the state foresters' efforts with those of other state and federal agencies. In addition, properly selected objectives can serve as a measure of success or failure of any effort made.

In my discussions with the several state foresters, I have noticed a concern for the finite and little evaluation of the broad picture. Planning is fast becoming a real and usable science over vast land areas. We can no longer proceed down various paths without coordination and mutual cooperation of many agencies and technologies. Land-use planning will have a profound effect on the type of assistance given by watershed foresters of the future.

For instance, there could be an operational plan to protect aquifer recharge zones critical to municipal water supply in a distant city. Forests may be encouraged along streams to stabilize banks, reduce temperatures, and improve oxygen levels of the state's water. Buffer zones could be set aside to prevent sediment from entering and polluting the water supply.

These problems are usually associated with property owners. They are broad public problems that are getting more attention each day. It is for these compelling reasons, among others, that a set of goals and objectives should be developed for municipal-watershed management. Whenever a forester makes a set of recommendations or assists a landowner, he would do a better job for both his customer and his state if he knew in advance what the landowner's management goals and objectives are for the area involved.

Another point worth pondering is that laws about how land can be used or what constitutes a public area of concern have shifted sharply in the last few years. A well-thought-out set of goals and objectives would assist a state forester in constructive response to any given legislative effort.

## AN EXAMPLE

You may be interested in a New England city's recent predicament and the service rendered to help alleviate the problem.

Adjacent to the municipal watershed, a builder proposed constructing a series of condominiums. A septic system was to have provided sewage treatment. Naturally, the city was concerned with its water supply and possible contamination. A new state law provided the municipality with a means of protecting its interest in clean water, but technical help was needed to evaluate the problem and state the city's case.

The State Forester responded to the city needs and request for help. Unable to supply a forest hydrologist of its own, the state asked for federal help. On-the-ground inspections were made and reported. An expert witness was provided at a hearing to assist the city during litigation.

This action resulted in a precedent-setting decision for the city. A potentially dangerous land use was successfully prevented before damage was done. A team effort protected the public interest. This time it was a city, state, and federal response.

## RECOMMENDATIONS

In conclusion, I feel that state technical assistance on municipal watersheds as it exists now is passive. There is reaction to a call rather than action for a cause. To improve this condition and hasten an effective municipal watershed program, I suggest the following:

- Each state forester should have a set of coordinated goals and objectives for municipal watersheds in his state.
- There should be federal and state cooperation in developing needed watershed programs and the necessary financial support.
- Forest Service hydrologists and other available technologists should be made available to train state personnel upon request.
- The Forest Service, the universities, and state agencies must help provide suitable guidelines and management procedures for use in watershed management.
- Symposiums to exchange ideas and procedures need to be continued by the state universities.

# SUMMARY OF MUNICIPAL WATERSHED MANAGEMENT SURVEYS IN THE EASTERN UNITED STATES

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*ABSTRACT.* The U.S. Forest Service conducted two municipal watershed management surveys in the eastern United States, using mailed questionnaires, to (1) determine the importance of surface water supplies, (2) inventory the land uses allowed in these watersheds, (3) inventory the nature and extent of various land-management problems related to water supplies, and (4) determine what information and management practices are needed to improve watershed management and water supplies.

THE U.S. FOREST SERVICE, through its Northeastern and Southeastern Forest Experiment Stations and the Southeastern Area Office for State and Private Forestry, conducted two municipal-watershed-management surveys in the eastern United States, in the Northeast in 1968 and in the Southeast in 1972 (fig. 1). The Southeastern study also included Arkansas, Louisiana, Oklahoma, and Texas; but for the purposes of this summary only those states east of the Mississippi River are included.

Both studies had basically the same objectives: (1) to inventory the land uses allowed in municipal watersheds; (2) to inventory the nature and extent of various land-management problems in these watersheds; and (3) to determine what information, research, and types of management practices are needed to improve the management of municipal watersheds.

Different definitions of a municipal watershed were used in the two surveys, and this influenced some of the results. In the Southeast, a municipal watershed was defined as *any* watershed that supplied surface water to a community, whether or not any portion of the watershed was owned or controlled by a water-supply agency (fig. 2). In the Northeast, a municipal watershed was defined as one in which a water-supply agency owned land and "the primary function is to provide domestic water supplies, whether in public or private ownership, including protection land surrounding reservoirs and forest land managed for the protection of well fields and their

Figure 1.—The areas for which municipal watershed management was surveyed and summarized.



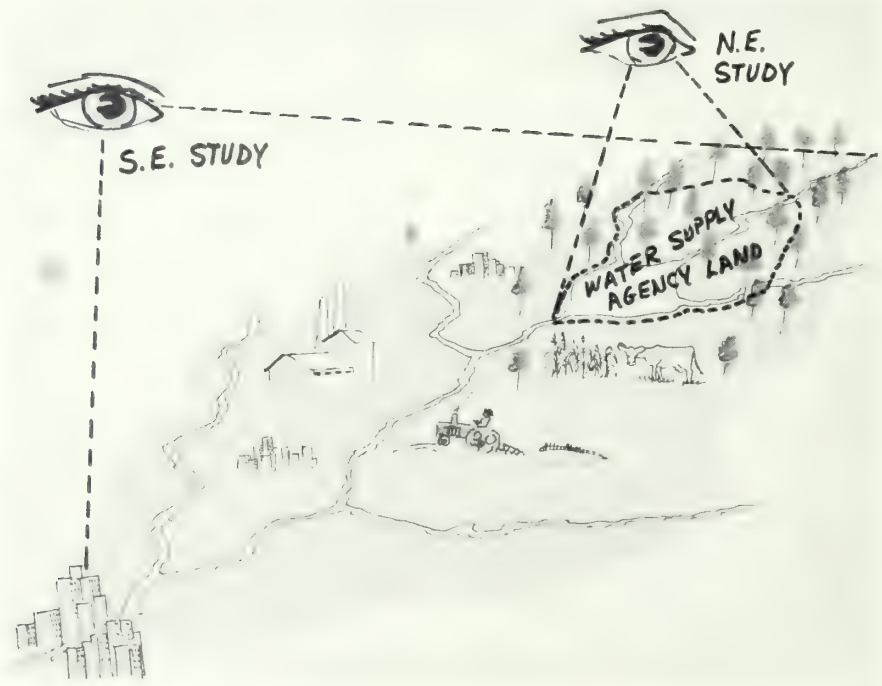




Figure 2.—The types of watershed surveyed.

recharge areas". A municipal watershed manager, therefore, is an individual whose responsibility is the care and management of such lands *(Corbett 1969)*. The Southeastern study did not include well fields or recharge areas. The Northeastern watersheds sampled were predominantly forested, whereas the Southeastern watersheds contained a mixture of land uses.

## SURVEY PROCEDURES

In both studies, questionnaires were sent to municipalities and water-supply companies. In addition, in the Northeast, questionnaires were sent also to state and federal agencies. Mailing lists were compiled from available records of state and federal agencies, publications, and a previous survey. 1,332 questionnaires were mailed in the Northeastern survey and 631 in the Southeastern survey. Two months after the questionnaires were mailed, a follow-up mail contact was made with the nonrespondents. In the Northeastern study, the nonrespondents who were known to own part of a watershed were asked by phone for data on the acreage of ownership. In the Southeast, no phone contacts were made except in Georgia *(Shaw 1973)*. Respondents to the Southeastern survey ranged from mayors and water-supply managers to clerks who used available data and personal knowledge to complete the questionnaires. The Northeastern survey had 78 percent response, the Southeastern survey 53 percent.

## EXTENT AND OWNERSHIP

In the states surveyed (fig. 1), at least 1,930 watersheds are used as sources of water. In the Southeast, the 337 water-supply agencies and companies that responded to the survey tapped at least 244 streams and 142 lakes and reservoirs to provide water for approximately 10,400,000 people — approximately 1,640 million gallons per day.

Several large rivers are tapped for municipal water; for example, the Chattahoochee, Tennessee, and Mississippi. In the Southeastern survey, 20 percent of the streams used had watersheds greater in area than 1,000 square miles (table 1).

Table 1.—Watershed size-class distribution in the Southeast and Northeast, in percent

| Watershed size class (square miles) | Southeast | Northeast |
|---|---|---|
| <5 | 18 | 54 |
| 5–9 | 11 | 13 |
| 10–49 | 23 | 18 |
| 50–99 | 10 | 7 |
| 100–499 | 14 | 7 |
| 500–999 | 4 | 0 |
| 1000+ | 20 | 1 |

However, when one contemplates management of municipal water-supply watersheds, one must limit consideration to relatively small watersheds, where land management can be influenced by a community or a water-supply agency. The practical limit to the size of such a watershed is probably 100 square miles. In our surveys we found that most of the watersheds used were of less than 100 square miles, (62 percent in the Southeast and 92 percent in the Northeast: table 1).

The ownership mixture varies between the Southeast and Northeast. Because the Northeast watersheds all had ownership by a water-supply agency, there is a difference in the interpretations that can be made from the data. In the Northeast, approximately 29 percent or 2,000,000 acres of the total watershed areas was owned or control-

led by 750 municipalities, private water companies, and state and federal agencies. These agencies manage these areas primarily for water supply. Of this acreage, 41 percent is owned by municipalities and 13 percent by private water companies; 36 percent is under state control and 10 percent federal control. The average size of such holdings is 4.2 square miles.

However, the remaining 71 percent of the total area is managed for other purposes. This consists of private, federal, state, and local government ownerships, the mix of which is unknown.

In the Southeast, the total watershed acreage is 15 percent in municipal ownership, 1 percent state, 11 percent federal, and 73 percent private and industry. The 15 percent of municipal ownership is spread over 46 percent of the watersheds.

## LAND MANAGEMENT

Land uses and management varied between the two regions, and this is reflected in the water problems identified. Though the Northeastern watersheds were predominantly forested, the respondents to the survey in the Southeast estimated that forest occupied 53 percent of the watershed areas. A significant difference is that 68 percent of the Southeastern respondents estimated that 24 percent of the area was used for agriculture and 9 percent for range. This creates significant agriculture- and livestock-related water problems. For those watersheds in the Southeast with municipal ownership, the forest occurrence and area increased to 93 and 58 percent, respectively. The area of brush is 11 percent with agriculture and range lands reduced in area.

The Northeast watersheds all have forest lands which occupies 71 percent of the area (table 2). Twenty-six percent of the watersheds are 100 percent forested. An additional 25 percent are 90 to 99 percent forested.

Control of activities on land owned by water-supply agencies in the Northeast is strict: 41 percent of these ownerships are closed to use; 59 percent allow some type of recreation. The restriction of uses on other lands in these watersheds were not evaluated. In the Southeast, only 11 percent of the respondents reported all or any portion of the watershed as closed. Seventy percent of the respondents reported no restrictions on

Table 2.—Percent occurrence and area of different vegetation types on watersheds supplying municipal water in Southeast and Northeast

| Vegetation type | Southeast | | | | Northeast | |
|---|---|---|---|---|---|---|
| | All watersheds | | Watersheds with municipal ownership[1] | | | |
| | Occurrence[2] | Area | Occurrence[2] | Area | Occurrence[2] | Area |
| Forest | 89 | 53 | 93 | 58 | 100 | [3]71 |
| Brush | 49 | 12 | 56 | 11 | — | — |
| Agriculture | 68 | 24 | 66 | 19 | [4]13 | — |
| Range | 32 | 9 | 30 | 7 | — | — |
| Other | 9 | 2 | 10 | 5 | — | — |

[1]Watersheds that contain some municipal ownership.
[2]Percent of responses indicating occurrence of a vegetation type within the watershed.
[3]Total area of non-forest conditions: 29 percent.
[4]Estimate based upon voluntary comments from Pennsylvania responses.

uses. Nineteen percent reported partial restrictions.

The permissiveness of activities is generally much greater in the Southeast (table 3). This is related in part to the types of watersheds surveyed. In the Northeastern study, activities were surveyed only on watershed land owned or controlled by the water-supply agency, while in the Southeastern study the activities were related to the total drainage area, most of which is not under management for water-supply purposes.

Special attention was given to recreation activities. The Northeastern watersheds allow little boating, swimming, and water skiing. Pressures on opening these watersheds for water sports is great, and there are requests for research to determine the recreational carrying capacities of watersheds without degrading water quality. Water-supply managers are seeking information for planning and managing recreation.

In the Southeast, a question asked was: Do you have watershed management agreements with outside landowners or other agencies? Negative answers were received from 78 percent of the respondents. However, 4 percent indicated that they had agreements with private landowners and 5 percent with the U.S. Forest Service. The remaining agreements were with industry and other federal and state agencies and were probably for water-supply or water-quality analysis.

## HYDROLOGIC AND WATER-QUALITY DATA

The type and quantity of hydrologic data collected were similar in both studies (table 4). In the Southeast, the emphasis on water-quality data was apparent: 79 percent of the watersheds collected raw-water quality data. Sixty-nine percent reported the parameters analyzed, including temperature, pH, turbidity, color, bacteria, suspended matter, and chemical constituents. The quantity of hydrologic data is limited for both regions.

Table 3.—Percent of watersheds on which various activities are allowed in the Southeast and Northeast

| Activity | Southeast[1] | Northeast[2] |
|---|---|---|
| Fishing | 87 | 39 |
| Hunting | 71 | 40 |
| Agriculture | 60 | [3]13 |
| Camping | 50 | 9 |
| Grazing | 49 | ([4]) |
| Boating | 48 | 11 |
| Swimming | 44 | 4 |
| Timber production | 44 | 54 |
| Horseback riding & hiking | 39 | 14 & 35 |
| Water skiing | 27 | 4 |
| Mining | 16 | ([4]) |
| Snow skiing | 7 | 7 |
| Ice skating | ([4]) | 8 |
| Other | 3 | 1 |

[1]Activities occurring somewhere in the total watershed, whether or not land was owned and managed for water-supply purposes.
[2]Activities only on land owned by water-supply agencies.
[3]Pennsylvania only.
[4]Not asked in survey.

Table 4.—Percent of watersheds on which different types of climatic and hydrologic data are collected

| Type of data | Southeast | Northeast |
|---|---|---|
| Raw water quality | 79 | ([1]) |
| Water temperature | 53 | ([1]) |
| Precipitation | 32 | 39 |
| Air temperature | 21 | 29 |
| Streamflow | 22 | 18 |
| Evaporation | 6 | 4 |
| Humidity | 4 | 3 |

[1]Not asked in survey.

## MAJOR PROBLEM AREAS

Municipal watersheds in the East are experiencing a variety of water problems. Corbett *(1969)* reported that 72 percent were concerned with water quality or water yield. In the Southeast, water quality is the biggest problem, followed by seasonal distribution of flow and total water yield (table 5). Although the Southeast is generally considered a water-abundant area, survey results indicated that 50 percent of the municipalities are concerned with seasonal distribution and yield problems. The seasonal distribution problem was reported primarily by communities that drew water from streams and lacked reservoirs.

Where water quality was a problem, the respondent was asked to indicate the sources of contamination (table 6). The leading source in the Southeast was agriculture and livestock, and in the Northeast municipal and recreation sources were of about equal importance. Municipal sources were also important in the Southeast, followed by recreation and industry. Pollution from farms in the Northeast was lumped with other sources and was not as common a problem as in the Southeast, but where it did occur it presented an important water-quality problem. Other than recreation, forest-related activities were a small percentage of the source of water-quality problems.

Table 5.—Percent of watersheds that indicate broad water-supply problems

| Problem | Southeast | Northeast |
|---|---|---|
| Water quality | 42 | 59 |
| Seasonal distribution | 29 | |
| | | [1]53 |
| Total yield | 21 | |

[1]The Northeastern survey did not differentiate between seasonal distribution and total yield.

Table 6.—Pollution sources within municipal watersheds, in percent of watersheds reporting a source of pollution

| Pollution source | Southeast | Rank | Northeast |
|---|---|---|---|
| | *Percent* | *No.* | *Percent* |
| Agriculture & livestock | 39 | 1 | [1]13 |
| Municipal | 30 | 2 | 38 |
| Recreation | 22 | 4 | 36 |
| Industry | 22 | 3 | [2]13 |
| Mining | 10 | 7 | — |
| Logging | 9 | 6 | 9 |
| Wildlife | 7 | 8 | — |
| Roads | 7 | 9 | — |
| Woodland grazing | 1 | 11 | — |
| Fire | 1 | 10 | — |
| Other | [3]30 | 5 | [4]30 |

[1]Based upon voluntary comments from Pennsylvania respondents.

[2]Industry included mining in Northeast.

[3]Other causes included color, odor, and taste from algae, swamp drainage, and urbanization.

[4]Other causes dealt primarily with water color, odor, and taste from algae, drainage from swamps and runoff from farms, road salting, and wildlife.

Water supply problems are not exclusively related to forest management, but forest practices and forest uses do have a role in accentuating or alleviating these problems.

## INFORMATION NEEDS

In the Southeastern survey, respondents were asked what types of forest-related information would be useful in making future decisions about their watersheds. The impact of forest management on the chemical composition of water was ranked highest (table 7).

They were also asked what land management information and methods would help them meet their water needs. Water quality again came to the forefront, water yield second (table 8). About 25 percent of the respondents were interested in technical assistance to improve land management.

Comparisons were made between Southeastern watersheds with and with-

Table 7.—Information thought useful for all Southeastern watersheds

| Impact of forest management on — | Rank: Sum of frequency an information need was ranked first, second, or third in importance | Responses indicating an information need |
|---|---|---|
| | *No.* | *Percent* |
| Chemical composition | 71 | 31 |
| Turbidity | 59 | 34 |
| Biological | 54 | 27 |
| Water yield | 51 | 24 |
| Recreation — bacteria | 44 | 33 |
| Recreation — chemical composition | 32 | 22 |
| Water yield timing | 24 | 15 |
| Temperature | 6 | 8 |
| Other | 1 | 1 |

Table 8.—Management information needed for future decisions in Southeast

[Percent of responses indicating need for land-management information or technical assistance.]

| Information needed | All watersheds | Watersheds without municipal ownership | Watersheds with municipal ownership |
|---|---|---|---|
| Land management for water quality | 33 | 28 | 38 |
| Land management to increase water yields | 26 | 22 | 31 |
| Technical assistance | 25 | 18 | 33 |
| Land management for water yield timing | 10 | 9 | 12 |

Table 9.—Publications received, by percentage respondents

| Publication | Southeast | Northeast |
|---|---|---|
| Water & Wastes Engineering | 70 | 49 |
| J. American Water Works Assoc. | 64 | 65 |
| Public Works | 53 | (1) |
| J. Water Pollution Control Fed. | 29 | (1) |
| Industrial Water Engineering | 20 | (1) |
| Farm Journal | 7 | (1) |
| J. Soil & Water Conservation | 1 | 19 |
| Southern Lumberman | 1 | (1) |
| Journal of Forestry | 1 | 17 |
| U.S. Forest Service Research Papers | 1 | 15 |
| J. New England Water Works Assoc. | (1) | 24 |
| Other | 6 | 5 |

[1]Not asked in questionnaire.

out municipal ownership. The only comparison that appeared to show a significant difference was in land-management information and methods (table 8). Managers of watersheds with municipal ownership appear to have a significantly higher interest in land management (80 percent level of confidence). The biggest difference was in technical assistance: 33 percent of those with municipal ownership showed interest.

## PUBLICATIONS RECEIVED

In the Southeastern survey, respondents were asked to list the journals and publications they receive that help them in managing their watersheds. The top five publications were trade journals that concentrate on water-supply management (table 9). Few respondents received publications that concentrate on land management. This indicates that land-management information is not reaching these people.

They were asked if they wanted to be put on a mailing list for publications relevant to land management on municipal watersheds. Sixty percent of the respondents requested being put on such a list.

## CONCLUSIONS

Municipal watersheds pose some challenging problems and opportunities in land management. Water-supply managers recognize the relationship between land management and water supply. Most watersheds are small enough that towns could influence the management of land within these watersheds. Consistently, water quality was the first concern, followed by water yield and recreational impacts. The leading causes of water-quality degradation were agriculture and livestock grazing, municipal, industrial, and recreational sources.

Interest in the impact of land use and management on the water resource is strong. Information is needed about the impact of forestry on chemical composition of water, turbidity, biological quality, and water yield. There is an interest in technical assistance in helping alleviate some of the problems.

The land management story may not be reaching the water-supply manager, and this may be preventing the improvement of management on these watersheds. More articles should be aimed at this audience through the trade magazines.

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# RESEARCH NEEDS RELATED TO MANAGEMENT OF MUNICIPAL WATERSHEDS

*by* ROGER R. BAY *and* J. S. KRAMMES, *respectively Chief of Watershed and Aquatic Habitat Research and Assistant Chief, Forest Environment Research, U.S. Forest Service, Washington, D.C. (Dr. Bay is presently Director, Intermountain Forest and Range Experiment Station, Ogden, Utah.)*

*ABSTRACT.* Major research needs in municipal-watershed management now center around the quality of water supplies, particularly the interactions between human activities on municipal watershed lands and water quality. We need to know the impacts of various intensive and extensive recreational activities and pressures on a number of water-quality factors. Knowledge is also needed on the effects of urbanization, on-site reservoir use, and other human activities. Prediction schemes and management recommendations need to be formulated. Foresters and resource managment specialists should also extend their concerns to management of undeveloped parcels of land such as green belts, flood plains, and park land.

THIS SYMPOSIUM has brought us up to date on physical, biological, and hydrologic processes and how we can manage municipal watersheds. In the last 10 to 15 years, long-term watershed experiments have produced results confirming earlier theories about land-water relationships and have extended our knowledge greatly, particularly in water-yield relations. We now know more about water-yield relationships in the forested mountains of the eastern United States than probably in any other region in the world. Although gaps certainly exist, we are not practicing all that we presently know, and various constraints may well prevent many types of watershed treatments. Building on this knowledge base, we now must consider where we should direct our present and future research efforts to meet the needs of planners and resource managers.

Some research needs have been identified. Our purpose is to suggest some ideas for thought and future discussion. I hope we can all extend our thinking to look at not only near-term problems, but also to research planning, longer-term problems, and needs. We can't discuss every research need; some of the obvious we will skip over.

We think of municipal-watershed management in terms of two broad categories: management of the area immediately draining into a water-supply system; and the broader concept of managing the land surface in the generalized urban-suburban complex, even though the area may not contribute to a municipal watershed as a supplier of water.

## THE MUNICIPAL WATERSHED

In any discussion of research needs for municipal watersheds, concern over water quality has to be first on the list. By water quality we mean impairment of water that may prevent or restrict particular uses. Water for human consumption is most important. Lower on the scale might be quality levels that limit swimming, fishing, and boating. Of course, we're concerned with esthetics and excessive algal blooms, suspended sediment, and accelerated weed growth that may lower the quality of recreational experiences for users. What management practices contribute to bringing about water quality changes? Can we suggest alternative management practices that may enhance water quality?

## RECREATIONAL USE

Information is needed about the impacts of a variety of recreation-associated land uses on water quality. This need is not limited to municipal watersheds, but answers obtained in other research disciplines, as well as studies of basic hydrologic processes on any watershed area, will be helpful. Land uses of primary concern are those most likely to occur on or within municipal watersheds, particularly recreational-use impacts. These can vary from extensive use such as hiking, horseback riding, and hunting to very intensive uses such as well-developed picnic and camping sites, boating, swimming, and summer-home development.

Research should be aimed not only at assessing impacts, but also at providing information for the proper planning and management of activities to prevent particular adverse impacts from recreational uses.

Relationships between management of intensive and extensive uses and the basic resources of soil, geology, and vegetation need to be quantified. Pressure to use underdeveloped areas for recreation seem destined to expand in the future, but our basic resources and their capacity to assimilate man's activities are limited.

## FORESTRY AND AGRICULTURE

The use and management of forest and agricultural land within municipal watersheds will have impact on water quality and yield. But intensive management practices, such as the use of fertilizers, other chemicals, and land disturbance, are research topics. Intensive management practices will likely be applied where vegetation, soils, and other factors are favorable. However, intensive management will not be practiced everywhere, and researchers must be aware of the views and plans of foresters and agriculturists to avoid expending resources on low-priority problems. For example, studies of fertilization in low-value hardwoods would not have high priority.

Research is presently directed towards intensive forestry practices in various sections of the United States, and these studies will apply to municipal watershed management. More information is needed on the integration of uses within a complex watershed and the effect of a variety of activities on water-quality parameters further downstream.

Watershed research should be concerned with problems of managing reservoirs and areas in and around streams. What types of in-stream water activities will adversely affect water-quality values? What type of vegetation cover is best on the immediate shoreline of a reservoir, particularly one that fluctuates widely? Do certain reservoir management practices encourage adverse impacts? Identification of potential research problems such as these is also part of municipal watershed manage-

ment. Our thinking must extend beyond the land area.

## URBAN SOIL AND WATER PROBLEMS

Planners, resource managers, and researchers should also be addressing soil and water problems in the broad urban-suburban complex. A number of hydrologists have studied the effect of urbanization on runoff and water quality.[1] Generally, these studies have concentrated on effects on the hydrograph, including peak flows, flow duration, and total water yield. Less effort has been applied to developing low-cost effective means of reducing excessive erosion and soil loss during the active construction phase of highways, shopping centers, or homes.

We don't know many of the impacts of the tremendous amounts of chemicals applied to urban areas — lawns, streets, and parking lots. Nor even the impacts of highway contaminents on surface and ground-water resources. In addition, we should consider the water-resource problems resulting from road design, location, and construction.

As watershed scientists, we could also turn our attention to the placement, design, and use of greenbelts, parkways, and other open areas for soil and water protection purposes. Can we help planners select greenbelts along stream courses to protect water quality and input to a reservoir? Can we offer guidelines on the width or size of streamside protection zones based on soils, rainfall, and channel characteristics? Should certain uses or activities be prohibited in such areas because of potential damage to soil and vegetation? A whole host of researchable questions might be posed concerning the selection and management of land and vegetation surrounding streams and reservoirs in and around urban areas. And what people are better qualified to consider such questions (and perhaps to pose new ones) than those concerned with soil and water management?

## RELATED ACTIVITIES

Research performed in other geographic areas and in related disciplines will have application to municipal watershed and urban hydrology problems. Most useful will be studies of basic processes involving soil-water and plant-water relationships. Understanding the dynamics of soil-water movement and identifying critical water-source areas will lead to improved watershed management.

Studies concerned with waste recycling have high priority because of the potential use of wooded and open lands near urban centers for this purpose. Under the right conditions, liquid wastes could be recycled on watershed lands where the potential recharge water may be highly valuable. In effect, we could be recycling the water back through a municipal watershed system.

Other studies dealing with water quality, such as methods of effectively monitoring (how, when, and where to monitor) sensitive water-quality parameters, would be helpful to various resource managers. Research on chemical transport processes and subsequently the modeling of such processes are needed in both urban and wildland situations.

We have tried to point out some of the broad research needs in watershed management. To do an effective job, managers need information about the related economic and social benefits and costs associated with the various land-management practices.

Finally, although not a research topic, we do see a real need for planners and managers to keep research scientists in-

[1]Knapp, G. L., and J. P. Glasby. 1972. URBAN HYDROLOGY — A SELECTED BIBLIOGRAPHY WITH ABSTRACTS. U.S. Dep. Inter. Geol. Surv. Water Resour. Invest. 3-72.

formed of their research problems in this complex field. And, since communication is a two-way street, researchers must keep in close touch with management concerns and continually strive to place the latest information and research results into the manager's hands.




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A report on the Symposium held in September 1973 at Pennsylvania State University and University of New Hampshire, containing 24 papers presented at the meeting.

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by Benjamin A. Roach

# Scheduling Timber Cutting for Sustained Yield of Wood Products and Wildlife




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## FOREWORD

This paper was presented as a talk at the Timber/Wildlife Management Symposium held in January 1974 at the University of Missouri, and the proceedings of the Symposium were published as Occasional Paper 3 of the Missouri Academy of Science, 312 Curtis Hall, UMC., Columbia, MO 65201. The paper is reprinted here after amendment and revision.

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MANUSCRIPT SUBMITTED FOR PUBLICATION 16 SEPTEMBER 1974

# Scheduling Timber Cutting for Sustained Yield of Wood Products and Wildlife

by Benjamin A. Roach

## ABSTRACT

Providing relatively uniform yields of hardwood timber for future generations will require adjustment of the presently unbalanced age-class distribution in the eastern hardwood forests. Because the home ranges of most species of wildlife are relatively restricted, maintaining stable wildlife populations throughout these forests will require adjusting and regulating timber age classes by much smaller units of land (several hundred to several thousand acres) than would be needed for sustained yield of timber alone. It is commonly believed that regulating timber production by such small units of land would be prohibitively expensive. But where the small unit has an age-class distribution approaching the average distribution for the forest as a whole, cost increases should be insignificant. The key to successful regulation of timber age classes for combined timber and wildlife production, with minimum impact on costs and timber yields, is the long-term planning of cutting schedules for small units of land.

MY MAJOR PURPOSE in this paper is to show the need for planning timber cutting a long way ahead — for either timber production or wildlife production, but especially for wildlife. A secondary purpose is to show how I think we might go about it.

## GENERAL ASSUMPTIONS

My first assumption is that future generations will need all the timber that can be produced, but will always be willing to trade off some timber growth for other benefits — wildlife, water, recreation, and aesthetics.

Another basic assumption is that assuring full and dependable timber yields over long periods — sustained yield, in other words — will necessitate a regulated distribution of timber age or size classes, at least in the general forest zones on public lands and increasingly on industry lands.

A third major assumption is that even-aged management will be the system of management generally used to regulate large-scale timber production because:

- Single-tree selection cutting can be used only for tolerant species, and even for these it is much more difficult to regulate for sustained yield than is even-aged management.
- Single-tree selection cutting provides only one general set of habitat conditions over large areas and for long periods. It thus fails to provide the diversity of habitat required by many species of wildlife, and wildlife populations are correspondingly limited.
- Small-group selection cutting may provide acceptable habitat for many species of wildlife, and it may be used to reproduce most species of trees; but the extreme difficulty of controlling cutting rates under it will limit its usefulness to small tracts and other areas where regularity of timber yields is not required. In short, we can practice group-selection cutting, but we can't regulate it on large areas over long periods.

That leaves only some form of even-aged management for large-scale production of timber and wildlife. I am talking about the general forest zone, not special areas where other uses may take precedence over regulated timber production. Please note, also, that even-aged management doesn't mean simply clearcutting some area every time the mood may strike. Rather it means carefully shaping individual timber stands through a long period of development toward a planned yield of specific products on a definite schedule, then harvesting when the objective is fulfilled and conditions needed for regeneration are present. The planned shaping of the stand is the basic feature of even-aged management, not the fact that clearcutting may have been selected for the regeneration method.

I have also had to make some subsidiary assumptions related to wildlife management. One is that it will be as impossible to optimize habitat conditions for all species of wildlife on the same area as it is to grow all species of trees on the same area. Therefore, both timber management and wildlife management must be coordinated toward production and maintenance of certain types and groups of species whose habitat requirements are compatible on a given area.

Another assumption is that the size of cutting area (stand size) adopted for timber management must be coordinated as far as possible with the habitat requirements of the wildlife species to be favored.

And a final assumption is that many wildlife species require some diversity of habitat, by which I mean the appropriate variety of plant species and successional stages that the animal must have continually in order to live in the area. A corollary is that, for maximum sustainable wildlife populations, the diversity must be supplied within areas judged to be roughly equivalent to the bird's or mammal's home range. Timber management requires having all size classes of trees from seedlings to mature timber, each size class or structure adding its own peculiar contribution, or impact, to habitat.

Therefore, it is the responsibility of the timber manager to provide the necessary range of stand structures, or conversely to disperse the unsuitable structures for minimum impact, over the wildlife species' home range. Basically, this means that timber-cutting schedules must be more stringently controlled for wildlife benefit than would be necessary for sustained yield of timber alone, and that the control must be exercised on smaller units of land.

I propose to examine the implications that this last assumption holds for timber management to see if certain basic adjustments can reasonably be incorporated in a timber-production program, and if possible to get an idea of the magnitude of costs involved.

## A MANAGEMENT EXAMPLE

Obviously I can't cover the whole field, and I don't know enough about wildlife management even to try. Therefore, I'm going to work with a specific example, featuring species with which I am at least a little bit familiar. I am going to try, on paper, to manage a hypothetical compartment on a large forest for combined production of oak timber and white-tailed deer. And since I like to hunt grouse too, I'll try to at least keep them in mind from time to time. Please remember that this is only an example. Different types or different species would require different solutions. I'm merely trying to illustrate a method.

My compartment is 1,000 acres of oak. This may be somewhat larger than the usual concept of a unit of deer range, but for a reason that will develop as I go along, I don't think it will make much difference in this case.

The timber-management objective on my compartment has been set for large sawtimber on a rotation of 100 years, with a 10-year cutting interval.

### Choosing Average Stand Size

One of the first things I must do is decide on the average size of stand that I want on this compartment, and there are a number of considerations that bear on the decision. The trees don't care what size stand they grow in as long as the area is big enough for satisfactory regeneration and development. Any size from about ½ acre on up will be satisfactory to the trees.

For administering the timber-management program, a relatively few large stands make for convenience and easier control. Timber operators like large stands, too, because they don't have to move so often, and their administration and supervision can be more routine. In both cases, though, as long as a stand is large enough to provide an economic cut and satisfactory administrative control, it's doubtful that efficiency will improve much with larger stands.

To the silviculturist, large stands are a mixed blessing. On the one hand, large stands mean less work drawing stand boundaries and fewer stand examinations and prescriptions. On the other hand, the larger the stand, the more variation there is in such things as site quality, and the less accurate the prescription will be. In my opinion 20- to 30-acre stands seem about right for the types I'm familiar with, although there are many areas where smaller or larger stands would be satisfactory for silvicultural purposes.

As far as the deer are concerned, the main factor is probably the amount of browse and herbage produced when stands are regenerated. If stands are too small, a large deer population can wipe out tree reproduction when we try to regenerate. If stands are very large, much good browse and herbage is unutilized. But deer don't seem to be very good surveyors, and they are blessed with the means to get quickly from one place to another when the mood strikes. So I doubt that any size between 5 acres and 100 acres is going to make much difference to a deer if the width of the area is not too great and if the surrounding area provides the other requirements for a suitable habitat.

But a 100-acre stand seems pretty large for grouse. One authority recommends 5-acre stands in a 20-acre grouse range in aspen. The 5-acre stand seems a little small for both timber management and deer management, so I compromised on a 20-acre average stand size. This is what I will work for on my compart-

ment. The administrator and the logger should be able to live with this stand size. The deer don't really care, and it should be at least several times better for grouse than 100-acre stands.

Because I want to keep my first attempt at combined timber-wildlife production as simple as possible, I am happy to discover that my sample compartment is all the same timber type and site class (mixed oak, site index 70). If I'm successful on my first attempt, I can work in the other complications later.

## Adjusting Timber Age-Class Distribution

If I were concerned only about timber production I would not try to regulate timber age-class distribution on an area as small as 1,000 acres. I'd combine the compartment with many others and work toward a balanced distribution over perhaps 50,000 or 100,000 acres.

Management for deer entails a different dimension. From what I've seen and read, deer make much use of open, newly regenerated areas, of brushy sapling-filled areas, and of areas of mature timber in close combination with these. But deer seem to spend little time in dense stands of poletimber from which they get little food and apparently little enjoyment.

There's no way that we can grow timber from sapling size to large sawtimber without going through a long pole stage. Thus it seems to me the only way we can grow timber on an area without having the deer break their lease for long periods is to keep the pole stands interspersed with enough younger and older stands within the deer's normal range to satisfy the animal's requirements.

The best that I can arrange for the deer on my compartment, and still grow timber efficiently, is to balance the timber age-class distribution on it. This arrangement will provide the maximum continuous proportion of non-pole timber. Ideally, then, at any time 10 percent of the timber stands on the compartment should be 0 to 10 years of age, 10 percent should be 10 to 20 years of age, 10 percent should be 20 to 30 years of age, and so on.

COMPARTMENT 1 YEAR : 1974

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 80 | 70 | 70 | 70 | 70 | 70 | 60 | 60 | 60 |
| 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| 60 | 60 | 60 | 60 | 60 | 50 | 50 | 50 | 50 | 50 |
| 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 10 | 10 |

Figure 1.—Age distribution of timber stands on sample compartment.

To get this distribution on my sample compartment I will have to regenerate 100 acres of timber on the compartment every 10 years. There's no other way.

One of the key factors that will determine the approach to regulated age-class distribution on my compartment is the distribution now present. And I discover that, unfortunately, the present age-class distribution is nasty; most of the compartment is in middle-aged stands:

| *Age class (years)* | *Percent of area* | *Number of 20-acre stands* |
|---|---|---|
| 80 | 4 | 2 |
| 70 | 10 | 5 |
| 60 | 36 | 18 |
| 50 | 30 | 15 |
| 40 | 16 | 8 |
| 10 | 4 | 2 |

And to make matters even worse, the age classes are not distributed at random but are concentrated in blocks (fig. 1).

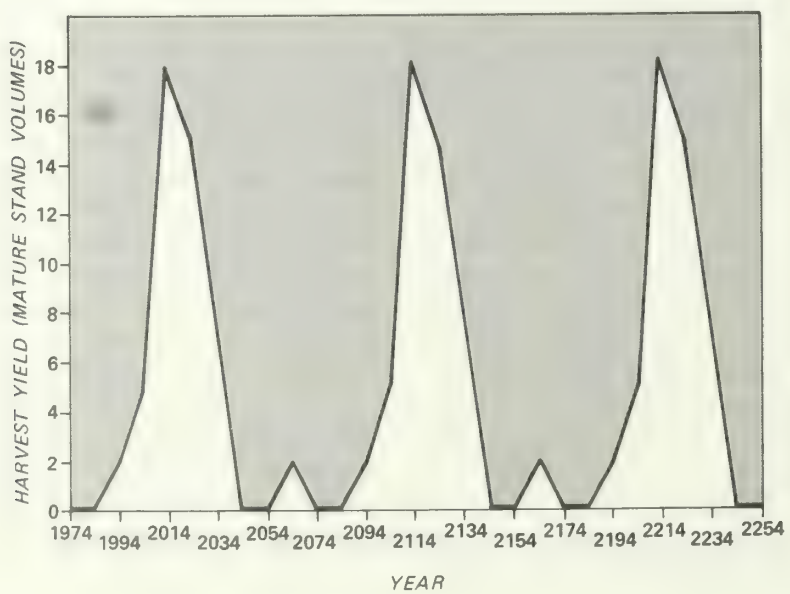
## COMPARING YIELDS UNDER DIFFERENT CUTTING SCHEDULES

To compare different cutting schedules later, I need to establish the pattern of yield and the volumes that would be obtained if I didn't try to adjust age-class distribution but simply perpetuated this one, cutting individual stands as they reach maturity (fig. 2). The unit of volume that I used is the harvest yield of one mature 20-acre stand. In other words, when I cut one 100-year-old stand of 20 acres, I get one harvest yield unit.

Since the oldest stand on the sample compartment is 80 years old in 1974, under the system of simply cutting stands as they mature, no stands will be harvested for 20 years. In 1994 two mature stands will be harvested. In 2004 five more stands will mature and will be harvested, and so on. After 90 years, in the year 2064, the entire compartment will have been cut over and will have provided 50 full harvest yields.

Incidentally, this schedule of cutting is the only one that causes no reduction in total yields. Any cutting schedule that changes the present timber age-class distribution on this compartment will reduce total yields over the adjustment period. But it seems obvious that some adjustment is desirable because the yield from just cutting stands as they mature is very uneven. A short period of timber abundance — 2014 to 2034 — will be followed by a long period of timber scarcity — 2044 to

Figure 2.—Yields expected from maintaining present age-class distribution.



2104. There will be a feast-and-famine cycle, a short feast followed by a long famine. There will be not only a feast-and-famine cycle in timber from this area; there will also be a feast-and-famine cycle for deer as the bulk of the area leaves the brush stage and goes through a long pole-timber stage.

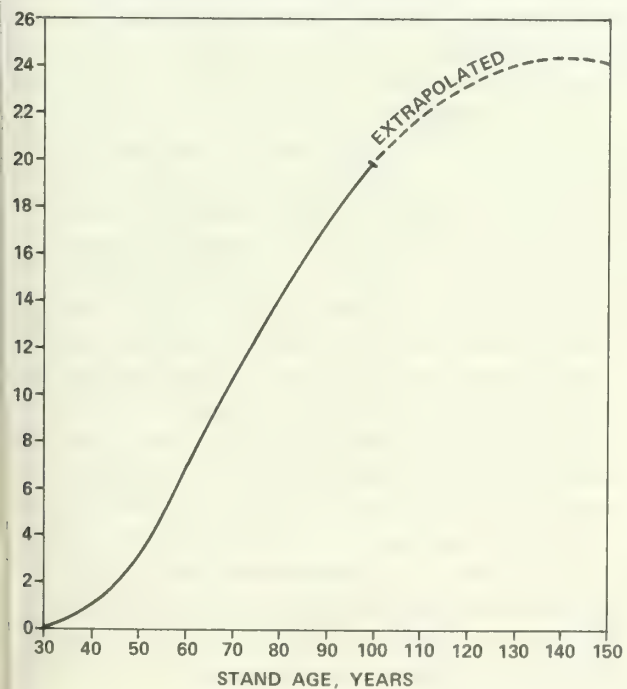
Many different cutting schedules could be devised to eliminate or reduce this feast-and-famine cycle. I will examine four alternative schedules that occurred to me and calculate the loss of yield that will result from each. Then I will add some simple constraints to improve or sustain deer habitat and see how much additional loss these would entail.

To compare wildlife and timber costs later, I need to determine the cost in physical yields that age-class regulation alone will entail on my sample compartment. I have calculated the expected yields for four alternative cutting schedules. For simplicity, and to make clear the basic principles involved, I am using only the final harvest yields to compare results of different cutting schedules. Thinnings can be used to help level out long-term yields, and they provide a powerful tool for helping adjust figurative age-class distributions. But they also add complications that I don't have space to discuss.

My figures are based on Schnur's board-foot Scribner yield table for even-aged oak stands, site index 70 — up to 100 years *(Schnur 1937)*. I had to extrapolate from there to estimate yields for older stands (fig. 3). My extrapolation is guesswork, of course, but the curve looks reasonable; and as long as the same curve is used for all cutting schedules, relative differences should be legitimate.

In the yield table I used, mean annual increment peaks between 100 and 110 years of stand age. Thus cutting stands younger than 100 years of age means a loss of production. And carrying stands beyond 110 years of age likewise entails a loss of production. The alternative cutting schedules that I examined all necessitate either cutting some stands early, or carrying some stands past maturity, or both, with corresponding decreases in total yield over the adjustment period. I will consider these losses of yield to be the costs of regulating age-class distribution.

**Figure 3.—Board-foot (Scribner) yield for even-aged oak, site index 70 (adapted from Schnur).**

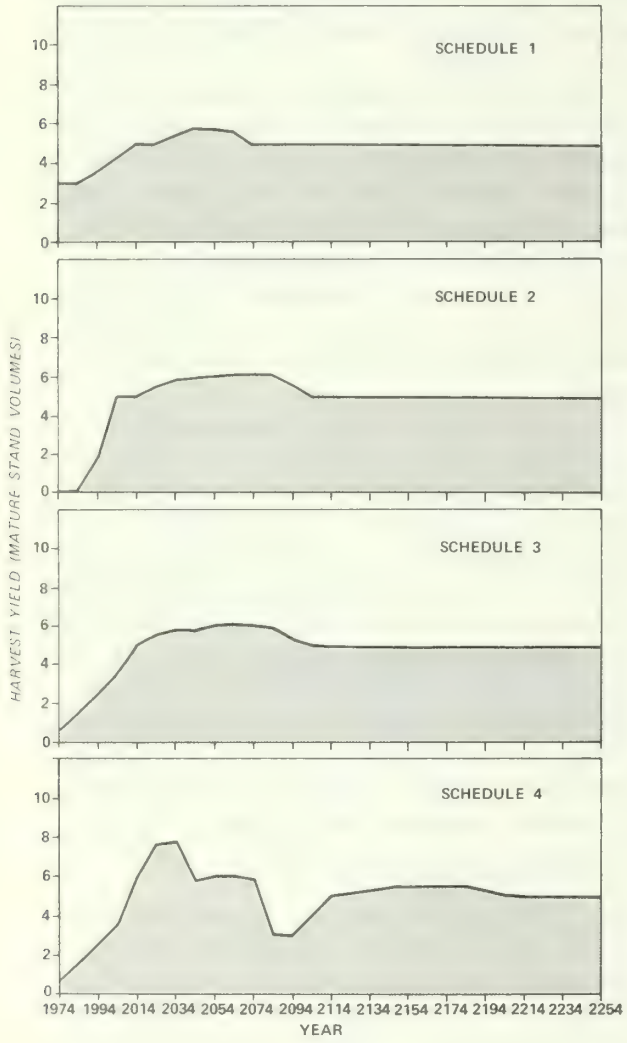



## Cutting Schedule No. 1

Once we decide that we need to break up this feast-and-famine cycle of timber yields and deer browse, one of the most obvious courses is to go all out for fully regulated yields as quickly as possible. With a 100-year rotation, a 10-year cutting interval, and 50 stands of 20 acres each in my compartment, I will need to regenerate 5 stands each cutting interval, the first cut taking place immediately. To avoid excessive loss of yield, I'll always cut the oldest stands first. I'll call this system Cutting Schedule No. 1.

Using this cutting schedule in my sample compartment requires cutting 6 stands 30 years before maturity, 9 stands 20 years early, 5 stands 10 years early, 5 stands 10 years late, 10 stands 20 years late, and 3 stands 30 years late. I will have achieved my desired distribution of age classes in only 90 years, and the pattern of yields has been greatly leveled out from the former pattern of feast and famine (fig. 4).

Figure 4.—Projected yields from cutting schedules.




However, Cutting Schedule No. 1 causes a reduction in yield over the 90-year period equivalent to the 100-year harvest from 3.36 stands (fig. 5). This amounts to 6.7 percent of the expected yield for the period. Three-fourths of this loss came from cutting stands before they were mature; the other one-fourth resulted from carrying stands beyond maturity.

Well, 6.7 percent of a rotation yield seems like a high price to pay for early regulation of yields, especially when the major impact hits us in the pocketbook within the next 30 years. And this sacrifice is only in physical quantities; it doesn't take into account the fact that the loss in value will actually be much greater. This is because present stumpage rates give a considerable bonus for large high-grade trees. When we cut stands early, the large high-grade trees are the very ones we're sacrificing. Since we can expect the stumpage differential between large and small timber to persist for the next few decades at least, cutting a stand early now means a much greater loss of value than cutting the stand the same length of time late. So the true loss from Cutting Schedule No. 1 will be relatively even greater than the 6.7 percent loss of physical yield would indicate.

We should expect considerable losses under this sort of schedule. Everyone knows that it's bad practice to cut immature timber.

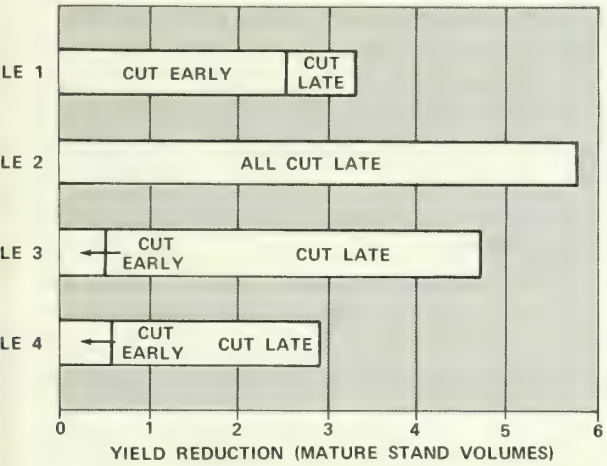
## Cutting Schedule No. 2

The large short-term loss from cutting immature timber can be avoided simply by letting stands mature before harvesting them. Cutting Schedule No. 2 is designed to explore this approach. Under this schedule I will still shoot for full regulation, but I will delay starting it until enough stands reach maturity to carry the full cut. I will begin harvesting stands as soon as the first ones reach maturity; and as soon as enough stands reach 100 years of age, I will regenerate 5 stands per cutting interval thereafter. I'll always cut the oldest stands first.

Under Cutting Schedule No. 2, no stands are cut early, but many must be carried beyond maturity; 5 stands are cut 10 years late, 7 stands 20 years late, 10 stands 30 years late, 7 stands 40 years late, 8 stands 50 years late, and 1 stand must be carried until it is 160 years old. It takes 120 years, only 30 years longer than the first alternative, to reach a balanced distribution of age classes; and this schedule provides a bonus 80 to 120 years from now of about 20 percent more timber than would normally be expected (fig. 4).

However, this has been achieved only at a great sacrifice of immediate volume. I get no harvest yields for 20 years. And you may be surprised to learn that, in fact, total loss of yield under this schedule considerably ex-

Figure 5.—Projected loss of yield from cutting schedules.




ceeds the losses under the first alternative. Total loss is equivalent to the harvest volume from 5.8 mature stands, or about 9 percent of the expected yield over 120 years (fig. 5).

At first sight this seems astonishing. How is it possible that the good guys who are only trying to prevent the cutting of immature timber would actually be causing a greater loss of yield than the self-admitted timber beasts?

The reason is that, as stands pass maturity, they add less and less volume. In fact, as they get older and start to deteriorate — and as insects, rot, wind, ice, and drought take their toll — stands will sooner or later start to lose volume. By delaying cutting of an oak stand on my compartment for 60 years past maturity, I estimate that I stand to gain only about 20 percent over the normal harvest volume. In the meantime, I've lost 60 percent of the next rotation. The loss is not just the volume that a 60-year-old stand would contain; it is 60 percent of the final yield of that stand, which is much greater. If you don't believe me, consider what would happen if I carried a stand for 200 years. For a nominal increase in the yield of that one stand, I would have lost an entire rotation yield from another.

The obvious course now is to see if I can find a compromise between the two extremes, and I'll briefly describe two that occurred to me. There may be better ones, but these will do for me until someone comes along with something better.

## Cutting Schedule No. 3

Cutting Schedule No. 3 is a one-rotation compromise; it simply splits the difference, so to speak, between the first two schedules. If you recall, under my first alternative I had 4 cuts before I was cutting any mature stands. In that period I had cut 20 stands. Under Cutting Schedule 3, I'll cut just half that many. I'll cut 1 stand in 1974, 2 in 1984, 3 in 1994, 4 in 2004, and thereafter 5 stands per period. As before, I'll cut the oldest stands first.

Under this schedule, it takes 130 years to reach full regulation; and during the last two-thirds of the adjustment period, the yield pattern is very similar to that of Cutting Schedule No. 2: between the years 2054 and 2094 there will be a 20-percent bonus of timber yields (fig. 4). The main difference from No. 2 is that we do get some immediate volumes. Compared to Cutting Schedule No. 1, however, short-term yields are considerably depressed.

The total yield loss under Cutting Schedule No. 3 exceeds the loss under my first alternative by 1.3 stands (fig. 5). However, over the adjustment period, the percentage loss is the same — 6.7 percent. Also, the large early loss associated with the first alternative is greatly reduced; only 11 percent of the total comes from cutting stands before maturity, compared to 75 percent for Schedule 1. The short-term impact is therefore very much less.

Compared to my second alternative, the loss from Cutting Schedule No. 3 is less by a full stand, and Schedule 3 does provide some immediate volume.

## Cutting Schedule No. 4

My last alternative—Cutting Schedule No. 4 — starts off like No. 3. During the first 4 cutting intervals, only 10 stands are cut. Then as soon as enough stands reach maturity, I cut more stands than called for—5 more as a matter of fact. Cutting more stands than called for gives increased yields in the middle

of the first rotation, which in turn causes decreased yields in the middle of the following rotation. In effect it means spreading the adjustment period over an extra rotation. Under this schedule it will be 230 years before the compartment is fully regulated (fig. 4).

Under Cutting Schedule 4, however, yield losses are the lowest of all — the equivalent of only 2.9 stands or 2.4 percent over the adjustment period (fig. 5). It does cause an up-and-down cycle in the yields that the others don't, and I can't predict how much this might pinch when the time comes. Compared to the other schedules, though, No. 4 holds the impact of both cutting early and cutting late to relatively low levels.

We might note that yields can be increased temporarily under any of these cutting schedules by adopting a shorter rotation. This cannot be done safely, though, unless the next generation stands are constantly thinned and perhaps fertilized from an early age, or unless product specifications and rotation objectives can be changed — for example to grow bulk fiber rather than board feet.

## SOME POINTS OF SIGNIFICANCE

Now, here are a few significant points that have emerged from my study thus far.

One is that our hardwood forests are badly unbalanced in the distribution of age classes of timber. This is because of the heavy cutting of timber that took place in the eastern forests from about 1890 to about 1935. Unless we begin exercising more thought toward the regulation of stocking and timber age classes within these forests, we are very likely to saddle the next several generations with recurring cycles of timber feast and timber famine.

We could say that, since the next several generations are bound to be smarter than we are, let them do it. This ignores the fact that we are in a better position to begin this regulation than will occur again for probably another 3 or 4 generations. The bulk of our timber is of an age where it will furnish reasonable volumes per acre, but it is not yet so close to maturity that initiating regulation will result in holding mature timber for long periods. Now is the best time for the adjustment process to begin.

The second key point is that, if the age-class distribution is unbalanced, correcting the distribution will in most cases reduce total yields over the adjustment period. It makes sense to begin looking for the lowest cost alternative.

Third, contrary to popular belief, when age distribution is unbalanced, refusing to cut timber until stands reach maturity is the most costly of all adjustment procedures in terms of lost production.

Finally, at least for those wildlife species that require some diversification of forest structure as their habitat, attaining a balanced distribution of timber age classes on areas as nearly as possible the size of a unit of the species' home range is probably the most important thing timber management can do to help stabilize wildlife populations and habitat and lay the basis for future management. And I propose to show that timber management can afford to do this on small units — in the range of 500 to 5,000 acres — and that the cost of doing so should generally be charged to the cost of regulation per se, and not as a cost of wildlife management.

## COSTS OF REGULATING AGE-CLASS DISTRIBUTION

The two basic costs of regulation are the loss of yield resulting from changing the age-class distribution and the out-of-pocket cost of administering the field work. I'll discuss the loss of yield first.

The age-class distribution on my sample compartment was chosen to approximate the typical distribution over a large forest. If the large forest has this distribution and if the whole forest is regulated for sustained yield under any of the cutting schedules I illustrated, the loss of yield over the forest will be the same, percentagewise, as I have shown for the compartment.

There is a major difference between the forest and my compartment, however; and

that is the manner in which the age classes are distributed. Over the forest, the age classes are not arranged in contiguous blocks; they are more or less randomly distributed, due to the nature of the early cuttings. It's fairly common to find blocks of several hundred acres of one age or size class. But due to variations in site quality and early cutting history, it's rare to find blocks as large as 1,000 acres that don't display a good deal of variation in stand ages, stand sizes, and stand structure.

On any small unit that has an age — or size-class distribution approaching the average distribution over the forest, the loss of yield from adjusting the distribution will be the same, percentagewise, as for the forest as a whole. In fact, it seems logical to assume that the distribution on the small unit can differ some degree from the forest average without a significant change in the yield loss, but I admit that I don't know how to identify the degree. My point is, though, that where a distribution approaching the forest average occurs on a small unit, why not take advantage of it? There would seem to be a considerable benefit to wildlife in doing so, and doing so would have little or no impact on yields.

It is true that if a small unit contains only one or two age classes, then regulating distribution on the unit would entail greater yield losses than the average. This increased loss would properly be considered a charge against wildlife, but it should be possible in many cases to enlarge the unit somewhat to include a greater range of ages. Another possibility is to use different thinning schedules in some stands of the same age to vary size-class distributions and hence prospective maturity dates.

So I'm not plugging for uniform 1,000-acre regulatory units throughout a forest, with uniform 20-acre stands. I'm saying we should take advantage of the opportunities presented in our present mixed-up forests to deliberately regulate by small units. Some might be as small as a few hundred acres, others might be several thousand acres. The forester and the wildlife manager working together should be able to work out cutting schedules in such a way as to greatly improve opportunities for wildlife management without any significant impact on timber yields.

But how about the administrative costs? Won't the dollar cost of administering the field work be greater for many small units than for one large one? No, they shouldn't.

Present working circles, or working groups, or regulatory units, or sustained-yield units — whatever you want to call them — derive from the time when selection cutting was our gospel. Under selection cutting, *if* we are managing species that will reproduce and grow under the system, and *if* we have a chosen diameter distribution established homogeneously throughout the unit, and *if* we apply selection cutting in such a way as to continuously maintain that diameter distribution, *then and only then,* regulation is automatic and differences between periodic inventories will reveal the amount and sizes of timber that can be cut from the unit in a given period. In our applications of the system we assumed that it didn't make any difference what part of the unit the volume came from because we could balance it out next time, though no one ever explained how a fixed homogeneous diameter distribution could be maintained by a hit-or-miss system of cutting.

Nevertheless, when all those "ifs" were satisfied, and assuming that our assumption was correct, large regulatory units made sense. The larger the unit, the more flexibility it offered, and the lower the administrative costs. For example, sampling intensity for inventory could be lower on large units.

Unfortunately, with the exception of a few research areas, I know of no place in the country where all those "ifs" were satisfied at the same time. In the great majority of cases none of them were.

Conversely, if the species is not adaptable to selection cutting, and if the diameter distribution is constantly changed by cutting or growth, and especially if we're using even-aged management by stands, then the difference between successive inventories is worthless for regulation and nearly always grossly incorrect as a guide to the allowable cut. If it is adhered to, it merely ensures that any

feast-and-famine cycles inherent in the present age-class distribution are continually perpetuated.

Well, if the old working-circle/periodic-inventory/cut-by-the-seat-of-the-pants method doesn't work, how can we regulate the cut? It's very simple. Basically, it's the same thing I did in calculating yields on my sample compartment. For any given regulatory unit we build the cut up, stand by stand. We know that in X years, stand A will be mature and will yield so much volume; we know that in X years, stand B will be due for a thinning that will provide so much more volume, and so on. We not only know how much volume will be available in any given year; *we know where that volume will be.* We can calculate how the volumes and the location of those volumes will change if we adjust age-class distribution. And we can explore alternative schemes for adjusting the distribution and compare the relative losses in reduced yield.

The groundwork for this is already laid, because we already use the individual stand as a basic control unit. We examine by stands; we make silvicultural prescriptions by stands; we mark timber by stands; we schedule and control cultural operations and logging operations by stands. It follows that, if we do everything by stands, it doesn't make any difference what sizes of regulatory units we have. The dollar cost of administering the regulation will be the same. The only possible difference I can see is whether it takes the computer longer to add up totals for 5,000 individual stands or by subtotals from 100 units of 50 stands each.

For the above reasons, then, if the age distribution on the regulatory unit is broad enough to make regulation feasible, the cost of adjusting age-class distribution on small units is a cost chargeable to timber management only, not to wildlife.

## TIMBER COSTS INCURRED FOR WILDLIFE BENEFIT

Now let's see what kind of costs are chargeable to wildlife, and if possible get some idea of the amounts.

### Constraints to Cutting

I want to re-examine Cutting Schedule No. 1. You will recall this was strict regulation, regenerating 5 stands per cutting interval, beginning immediately. After 90 years, the sample compartment will contain all age classes of timber from new regeneration areas to 90-year-old sawtimber. But these units are in 100-acre blocks. In effect I've made stands of 100 acres instead of 20 acres.

If the brushy areas were distributed throughout the compartment in 5 separate 20-acre patches, it would probably be a little more convenient for the deer. And the 100-acre patches are a long way from optimum for grouse habitat.

I don't know what the best compromise is, of course. I think the only thing to do is lock the forester and the wildlife biologist in a small soundproof room until they arrive at a mutually acceptable average stand size for any given regulatory unit. In the meantime I'll stick with my 20 acres. To help ensure good distribution of the 20-acre regeneration areas, I'm going to subdivide my sample compartment mechanically into 5 units, and each cutting interval I'll try to put one regeneration cut into each unit. This is my first wildlife constraint.

The extent to which this can be done successfully will depend greatly on the present distribution of age classes on the compartment. To keep yield losses as low as possible, I want to always cut the oldest stands first, and the location of the older stands within the compartment may be incompatible with spreading the cuts throughout. But I won't know until I try.

Also, to get as much diversity of habitat as possible, I'm going to enter another constraint. I will try to avoid putting a new regeneration area side by side or end by end with one cut 10 years ago. Diagonal is OK, but common boundaries aren't.

### Planning Cutting Schedules

The best way that I have found to go about planning these more complicated schedules is to get a number of outline maps of the compartment, with the stand boundaries on them,

from the Xerox machine. Then I enter the present stand ages on one of the maps, and pick out the stands for regeneration cutting during the first cut.

Next I take a second map and enter the stand ages as they will be 10 years after the first cut. And I select the stands that will be regenerated during the second cut. And so on.

I can't emphasize too strongly that *this planning process must be carried to completion* — to the end of the adjustment period. And if you'll take any assumed distribution of age classes by stands and try to make out a cutting schedule for it, you'll soon discover why. Everything would go smoothly for several cutting intervals. Then suddenly I'd find myself in a trap where either I had to cut an excessive number of stands early, or let some go for longer than necessary, or violate some wildlife constraints. Then I'd have to back up several cutting intervals and start over.

It is not very professional to put a forester several generations from now into a trap that proper planning and foresight on our part would have avoided. Therefore, I earnestly recommend that you get some compartment outline maps, set up some assumed age-class distribution and start investigating what can happen from incomplete or careless planning of cutting schedules. I think it will prove to be very instructive.

Actually, this process is what a mathematician might refer to as a spatial game. Such games are well adapted to computer solution, and I can foresee the day when this process will be handled by computers. But the average forester will probably not have ready access to a computer for several years yet, and he will be pleased to know that he can do a creditable job with paper and pencil and a couple hours of practice.

This is not to imply that, once adopted, the plans cannot be changed. They can be changed at any time. But each time a change is made, the new plan must again be carried through to the end of the new conversion period. Otherwise there will be no way to calculate the benefits and costs that the changes will entail.

Our inability to calculate the costs and benefits of alternative plans has been a major shortcoming of past planning procedures. A citizen's group may not like the cutting plans we are following and ask why we don't change the system and do thus and so instead.

The question has been difficult to answer satisfactorily because we have been unable to show the impact (or benefit) of the proposed change on production. We have been unable to say whether the change will reduce yields or not, or by how much. A procedure such as I have outlined will permit us to calculate the effect on yields of any changes in cutting policy.

### Yield Reductions from Wildlife Constraints

At any rate, I went through this planning process on my sample compartment for each of 4 cutting schedules we went through earlier — but this time with the wildlife constraints that I had imposed. Then I recalculated the yields. Table 1 lists the yield losses with and without the wildlife constraints that I assumed.

The main point to be noted here is that the added cost of constraints that I set up for wildlife benefit is only about ¼ to ⅓ as large as the cost of attaining age-class regulation per se. Of course, it would be possible to impose additional constraints that might greatly increase this cost. But I have a feeling that just the constraints I imposed here will go a long way toward helping to stabilize wildlife populations and helping to improve the dispositions of wildlife managers.

## SOME LOOSE ENDS

One is the question: What if my compartment is not exactly contiguous with a unit of deer range? I don't think it will matter very much. By the end of the first cutting interval, the same procedure should have been initiated in all the surrounding compartments. By 30 or 40 years later, timber age classes should be showing pretty good dispersion on my sample compartment *and on surrounding compartments*. No matter where that deer estab-

Table 1.—Yield reduction on sample compartment from different cutting schedules with and without wildlife constraints

| Schedule | Years to regulation | Yield loss | Yield loss | Loss due to wildlife |
|---|---|---|---|---|
| | *Years* | *Stands* | *Percent* | *Percent* |
| NO WILDLIFE CONSTRAINTS | | | | |
| Schedule 1: Immediate regulation | 90 | 3.36 | 6.7 | — |
| Schedule 2: Delayed regulation | 120 | 5.80 | 8.9 | — |
| Schedule 3: Partially delayed | 130 | 4.70 | 6.7 | — |
| Schedule 4: Partially delayed, extra rotation | 230 | 2.90 | 2.4 | — |
| WITH WILDLIFE CONSTRAINTS | | | | |
| Schedule 1: Immediate regulation | 100 | 4.55 | 8.3 | 1.6 |
| Schedule 2: Delayed regulation | 130 | 8.23 | 11.8 | 2.9 |
| Schedule 3: Partially delayed | 130 | 5.98 | 8.5 | 1.8 |
| Schedule 4: Partially delayed, extra rotation | 230 | 3.86 | 3.2 | 0.8 |

lishes his home range, the area should display about the same pattern of timber age classes as the unit that I initially assumed as the home range.

Another question is, How to handle differences in timber type and site quality within a compartment? I don't have time to go through the procedure I used, but briefly it consists of making stand boundaries conform to site-class boundaries, selecting appropriate rotation lengths for each site class or type-class, deciding on the age-class distribution desired in each site class when it is completely regulated, and then developing cutting schedules for each class as though it were a separate small compartment.

By plotting the planned regeneration cuts for each site class simultaneously on the same compartment map, adjustments in cutting schedules can be made as necessary to disperse cuts throughout the whole compartment.

Another question is how to handle unique or spatially recurring situations now included in timber compartments but that are not amenable to redistribution as timber age classes are. I refer to such things as spring seeds for turkeys, patches of aspen in an oak or northern hardwood type, or deer yards in the northern latitudes.

If such things are more closely related to the geology than to the timber type — spring seeps, for example, I think they and any necessary buffer zones should be excluded from the timber-management compartment, or at least excluded from the area regulated for timber production just as a picnic area would be. If they are more closely associated with the timber, they can be set up as a separate type or site class, with more specific wildlife constraints assigned, and managed accordingly.

## CONCLUSIONS

1. Providing relatively uniform yields of hardwood timber for future generations will require adjustment of timber age-class distributions for sustained yield. For most forest types I see no alternative.

2. Because of heavy timber cutting around the turn of the century, the bulk of our hardwood timber is now approaching maturity. Thus our generation is in a more favorable position to begin the adjustment than will

occur again for a whole hardwood timber rotation.

3. The regulation of timber age classes must be carried out deliberately but with careful foresight and timing. Pushing immediately for full regulation will cause a severe loss of timber values in the short-term future. Delaying initiation of regulation until present stands reach maturity will severely restrict short-term yields and cause large losses in total yield. Compromise alternatives are needed, based on relative costs involved.

4. Avoiding up-and-down cycles in wildlife populations necessitates continuously providing any diversity of habitat required by the wildlife species within the species' home range. Thus optimum yields of wildlife will require adjusting and regulating timber age classes by much smaller units of land than is needed for sustained yield of timber alone.

5. Regulatory methods and allowable cut determinations carried over from the practice of selection cutting are inapplicable and, with unbalanced age distributions, grossly inaccurate when grafted onto even-aged management. The proper method for even-aged management is the summation of individual stand volumes in conjunction with scrutiny of various possible cutting schedules. When this is done, the size of area regulated is unimportant from the standpoint of reduced timber yields — if the distribution of age classes on the small unit is not greatly different from the average distribution throughout the forest. If the small unit contains only one or two age classes, then regulation on the small unit can entail increased loss of yield in the initial rotation. In such circumstances the extra loss of yield is properly considered a charge against wildlife, or the regulatory unit should be enlarged to include a greater range of age classes.

The administrative cost of regulating age-class distribution should be about the same regardless of the size of the regulatory unit, if average stand size is not made too small for efficient operation.

6. Constraints for wildlife benefit such as deliberate dispersal of cuts will further increase cost of regulation, but this cost does not seem serious. Additional constraints may be more costly, but it is time for wildlife managers to present them for consideration in such a way that they can be quantified and scheduled. With my limited knowledge of wildlife needs, I can only guess at the type of constraints needed. I am saying to wildlife managers, the measures that I have outlined form a matrix within which I believe timber management can operate. What more do you need and how can we work it in?

I might note that we in timber management would appreciate it if you can arrange to monitor changes in wildlife populations as a result of changes in timber and habitat practices. Opinions are poor substitutes for hard data.

7. The key to successful regulation of timber age classes for combined timber and wildlife production with minimum impact on costs and total yields is the long-term planning of cutting schedules by small units of land. Such planning has been lacking in the past. Without such planning we have been unable to quantify and compare the benefits and costs of alternative approaches. We have expected the public simply to take the forester's word that he knew best, that he knew what he was doing, and that he had made adequate provision for forest uses other than timber production. And as you know, nowadays nobody takes anybody's word for anything.

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13 p., illus. (USDA For. Serv. Gen. Tech. Pap. NE-14)

Maintaining stable wildlife populations throughout eastern hardwood forests will require adjusting and regulating timber age classes by much smaller units of land (approximating the home ranges of the species involved) than would be needed for sustained yield of timber alone. The key to successful regulation for combined timber and wildlife production, with minimum impact on costs and timber yields, is long-term planning of cutting schedules and comparison of yields under alternative schedules for small units of land.

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# The Allegheny Hardwood Forests of Pennsylvania

*Their bounty of timber and deer are the results of events that occurred many years ago*

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*by David A. Marquis*

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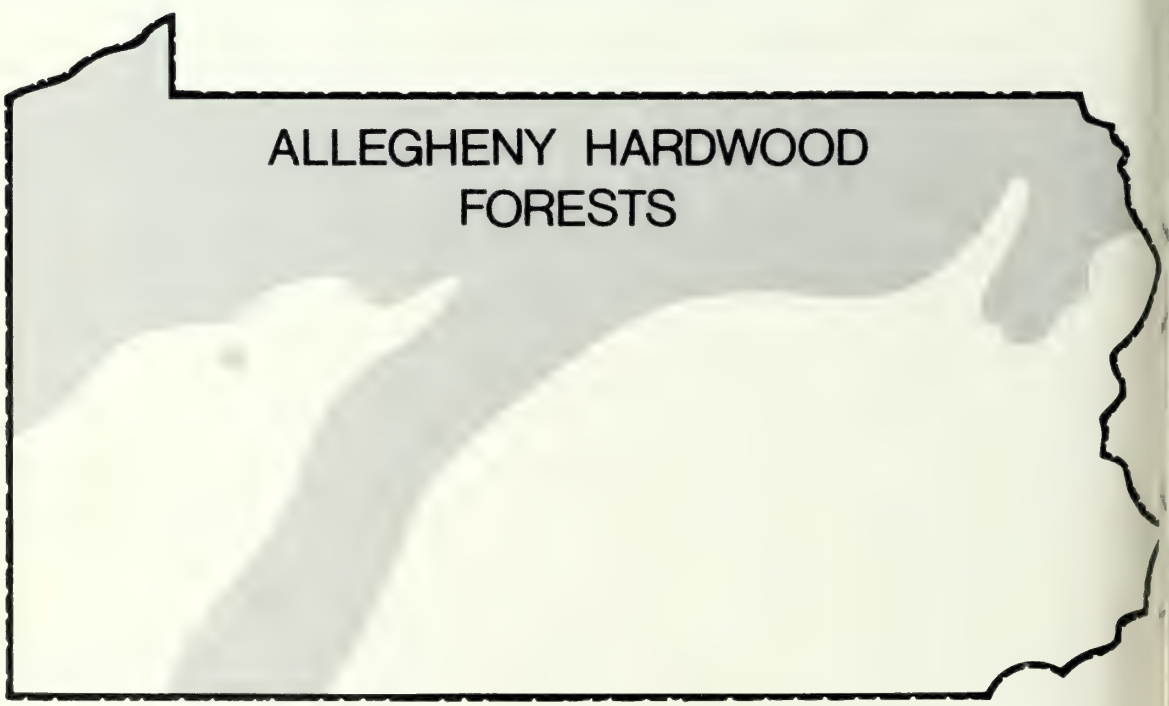
# The Allegheny Hardwood Forests of Pennsylvania


## ABSTRACT

Difficulties now being experienced in obtaining natural regeneration of Allegheny hardwoods after forest cutting have been puzzling, for the current cuttings are similar to those that produced the excellent stands present today. A search of historical material in northwestern Pennsylvania provides much insight into the changes that have occurred in forest conditions from the days of the Indian through the era of white settlement and industrial development up to the present. Two major changes seem to account for the present difficulties: a much larger deer herd now exists so that deer feeding on tree seedlings has become a major factor preventing new forest establishment; and present stands lack the well-developed seedling understory that was present in the original forests as a result of their overmature condition and long history of partial cutting. Thus the problems we now face in forest management as well as the bounty of timber and deer that we now obtain from these Allegheny hardwood forests both had their origins in events that occurred many years ago.


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COVER PHOTO.—A magnificent black cherry tree on the Allegheny National Forest. Black cherry is the most valuable of the species in the hardwood forests of the Allegheny Plateau.




The Allegheny hardwoods occupy the Allegheny Plateau in northern Pennsylvania and reach southward along the Appalachian highlands.

THE ALLEGHENY PLATEAU of Pennsylvania is blessed with fine forests of black cherry, white ash, sugar maple, red maple, and other hardwood species. These forests are a dominant factor in the pleasant environment of the region, and their products make major contributions to the economic and social well-being of many communities both within and outside the Plateau.

Allegheny hardwood forests provide the raw materials for a large and important wood industry. On the Pennsylvania part of the Plateau alone, there are some 670 wood-industry plants providing a payroll of about 140 million dollars to their 24,000 employees, and adding more than 275 million dollars to the economy each year (*Pa. Dept. Comm. 1972; U. S. Dept. Comm. 1971*).

Almost all the commercial black cherry timber in the country comes from the Allegheny Plateau. Factories as far away as South Carolina and Michigan depend upon this source of supply for the raw materials they need to produce fine furniture and veneer for cabinets and paneling.

Although commercial black cherry is unique to this region, the other hardwood trees on the Plateau are no less important.

White ash is the long-time favorite wood for such products as tool handles and baseball bats. Those Louisville Sluggers that are used to pound out home runs in major league parks

Many of the original forests on the Allegheny Plateau contained large mature and overmature trees—white pine, hemlock, beech, chestnut, black cherry, ash, oaks, and maples.



throughout the country may be manufactured in Kentucky, but the wood used in those bats very likely came from ash trees grown on the Allegheny Plateau.

The maples are well known to everyone as sources of lumber for furniture, for specialty products such as bowling pins and bowling alleys, for maple syrup, and for their spectacular orange-red fall foliage.

All of these Allegheny hardwood species—cherry, maple, and ash—have timber values that rank them among the most valuable woods in the world.

Allegheny Plateau forests yield many social and economic benefits other than timber products. Deer hunting is one major example. Pennsylvania ranks first in the nation in the sale of hunting licenses: between 100,000 and 145,000 deer are harvested annually (1967-72) in Plateau forests.

The direct expenditures for hunting by more than 80,000 deer hunters are estimated at over 100 million dollars annually. These figures tell only part of the story, however; for deer bring incalculable enjoyment to thousands of others who get their pleasure simply by observing or photographing these animals in their natural environment.

Fishing, hiking, camping, water sports, bird-watching, nature study, and other forms of outdoor recreation must also be added to the list of benefits derived from Allegheny hardwood forests.

## Tracing the Problems

But there are problems in managing these forests. One very important problem is a difficulty in establishing new seedlings in areas where trees have been harvested for timber.

In setting up a program of research to find solutions to this problem, scientists of the Northeastern Forest Experiment Station could not help but wonder why such a problem should exist now. After all, nature established the existing forests 50 to 100 years ago without any help from foresters. In what ways are conditions so different now?

In searching for an answer to this question, I examined many historical documents describing the forest conditions and the settlement of northwestern Pennsylvania.

Although the information presented here probably applies generally throughout the Allegheny Plateau, most of the historical sources examined refer specifically to Warren, McKean, Elk, and Forest Counties in northwestern Pennsylvania. This is the heart of the Allegheny hardwood region; the Allegheny National Forest lies entirely within these four counties.

Comparatively little information about forest conditions was found, but what data and descriptions there were, combined with our current knowledge of forest ecology, provide a reasonably clear picture of just what is different now and how the present conditions came into being. Both the benefits we realize and the problems we face today can be traced to events that occurred many years ago.

## Original Forest Conditions During Indian Times

The original forests of Pennsylvania covered nearly the entire land surface, except for a few natural meadows and rough mountain tops (*Illick 1923*). Many of these original stands were mature or overmature, containing trees of very large size.

This does not imply that all forests were primeval in character; disturbances such as fires and windthrow were apparently common (*Lutz 1930a*), so that there were many stands of different ages and species mixtures, representing various stages of recovery from natural catastrophies.

Indians were responsible for many forest disturbances. Almost all northeastern Indians lived in villages; they cleared land for these villages and for agriculture, and cut trees from adjacent areas for firewood. They often set fire to the woods to increase berry production, facilitate travel, and improve visibility, perhaps as an aid in hunting. Indian villages were relocated rather frequently as soil and firewood were depleted, so that the total area affected was considerably larger than that actually being used at any one time (*Day 1953*).

The Indians who occupied the valleys of the Allegheny River and its tributaries in northern Pennsylvania before the coming of the white man were Senecas. The Senecas were



A replica of a Seneca Indian teepee and burial platform. The Allegheny Plateau was Indian land; and the Indians cleared land for their villages and fields and burned the woods to aid in hunting and improve berry production.

members of the powerful Iroquois Confederation, which also included the Mohawks, Oneidas, Onondagas, and Cayugas (*Schenk and Rann 1887*).

Although there are reports of Seneca cornfields covering 500 acres or more along the Allegheny River north of Warren (*Day 1953*), and although there is much evidence of burial mounds, Indian stockades, and early earthworks (*Lobeck 1927*), there is very little solid information about the extent of their activities or their impact on presettlement forest vegetation.

However, Indians probably did have some effects. For example, it seems likely that the existence of the oak type along the Allegheny River and its tributaries is the result of fires set intentionally or unintentionally by Indians who lived, hunted, and traveled along the river. (Oaks are better adapted to resprout and survive after repeated fires than most other species.) Under our current forest fire protection programs, these oak stands are gradually being converted to other species.

## Original Forest Types

The forest types that were present before white men settled here were somewhat different from those present today. Most of the same species are still here, but their distribution and relative abundance have changed. Hough and Forbes (*1943*) recognized three types of presettlement stands:

*1. White Pine.* These were relatively pure stands that occurred in small well-defined areas—areas measured in tens rather than hundreds of acres. American chestnut, red maple, and oaks were often associated with the pine in these stands; but beech, cherry, and sugar maple were uncommon in this type.

Pure white pine stands generally originated after catastrophies that wiped out the preceding stands. Droughts followed by forest fires are known to have been the catastrophic agents in some cases, windthrow in others. In one virgin stand, it has been estimated, there were 85 fires from 1727 to 1927 (*Lutz 1930b*). Day (*1953*) suggested that abandoned Indian

clearings often grew up to pine. Pine stands occurred mostly on sandy river flats and terraces and on lower slopes where the soil was loose and sandy (*Lobock 1927*).

2. *Hemlock-Beech.* Hemlock and beech were by far the most common species in original stands on the Allegheny Plateau. Together, they represented 58 percent of all trees observed in early land-surveys of the area that is now the Allegheny National Forest (*Lutz 1930b*). They frequently occurred together and probably represent the true climax type of the area.

Although both species are tolerant of shade and will reproduce beneath their own canopies, the occurrence of both species can often be traced to periodic catastrophies (*Hough and Forbes 1943*). Hemlock was most abundant on moist sites along streams and poorly-drained uplands where it was protected from the periodic fires that burned through the area.

3. *Beech-Maple.* Sugar maple, an associate of the hemlock-beech type, often replaced hemlock as a major component. Sugar maple is also a shade-tolerant climax species, although it is less shade-tolerant than either of the other two.

Beech-maple stands were more common on the better drained or less moist areas, perhaps because hemlock was eliminated there by fires. Red maple, yellow and black birch, white ash, and black cherry were common associates in both the hemlock-beech and beech-maple types, with scattered distribution in both.

## Species Distribution

Perhaps the best data on relative abundance of the various species in the original forest are those obtained by Lutz (*1930b*) from examination of the original land-survey notes for an area that corresponds approximately to the present Allegheny National Forest. Although 32 species of trees were mentioned in those survey notes, relatively few of them made up the bulk of the stand. Beech and hemlock represented 58 percent; these two plus maple, birch, white pine, and chestnut represented 88 percent (table 1).

Crude estimates of frequency were also obtained from these data (table 1). Beech and hemlock were present on nearly all the survey lines, maple and birch on more than 80 percent of the lines, chestnut and white pine on about 60 percent of the lines. Most of the other species were encountered infrequently, suggesting that they probably occurred as solitary individuals or groups in the virgin forest.

There was little information about understory vegetation, except that laurel thickets were mentioned frequently in the notes. They were often referred to as "inextricable labyrinths".

The high frequency and low abundance of white pine, chestnut, and birch—and to a lesser extent maple—indicate that all these species were common, but that they rarely were a major component over sizable areas. Although white pine occurred in pure stands in some places, these must have represented a comparatively small proportion of the total forested area.

In many places, white pine also occurred as a minor component in other types, probably originating under a partial canopy after some

Table 1.—Original forest composition of Allegheny National Forest, in percent

| Species | Abundance[a] | Frequency[a] |
|---|---|---|
| Beech | 30.85 | 98.7 |
| Hemlock | 26.80 | 100.0 |
| Sugar maple | 13.04 | 81.5 |
| Red maple | — | 65.6 |
| Birch | 6.06 | 82.8 |
| White pine | 5.99 | 64.3 |
| Chestnut | 5.57 | 57.9 |
| Laurel | 3.92 | 52.2 |
| Ash | 1.04 | 31.2 |
| Sycamore | .62 | 19.1 |
| Oak | .57 | 15.9 |
| Magnolia | .42 | 12.7 |
| Sassafras | .42 | 6.4 |
| Ostrya | .33 | 11.5 |
| Hickory | .28 | 8.9 |
| Yellow-poplar | .23 | 7.6 |
| Basswood | .14 | 3.8 |
| Witch-hazel | .10 | 4.4 |
| Black cherry | .09 | 3.2 |
| Amelanchier | .07 | 2.5 |
| Carpinus | .07 | 2.5 |
| Dogwood | .05 | 1.3 |
| Alder | .02 | .6 |

[a] Abundance was calculated as a percentage of the total number of trees counted as corner or witness trees or otherwise mentioned in the land survey. Frequency was calculated as the percentage of survey lines on which that species was mentioned. From Lutz *(1930b)*.

minor disturbance that did not completely remove the overstory. Evidence for this sort of origin of the pine component of the hemlock-beech virgin forest at Heart's Content has been presented by Lutz and McComb (*1935*).

The abundance of white pine in presettlement forests has probably been overstated in many early accounts. This would be understandable in view of its occurrence in the valleys along transportation routes, and in view of its early importance in the lumber industry.

## Plenty of Wildlife

A great variety of wildlife inhabited the forests of the Allegheny Plateau before settlement by the white man. Of the larger animals, deer, elk, bear, wolves, cougars, wildcats, and lynx were all present. Some authors suggest that there were also moose and bison, but this has never been substantiated (*Clepper 1931, Doutt et al. 1966, Simpson 1890-1944*).

White-tailed deer were common, but not abundant during this time. Vast stretches of unbroken timber limited food, and predators helped to keep populations in check. Deer were probably more numerous in northwestern Pennsylvania than in eastern Canada, northern New England, and northern New York, where deep winter snows provided an additional handicap.

But deer were less numerous here than they were throughout the oak forests of the Ohio and Mississippi River valleys where plentiful acorns and more moderate winters provided better conditions (*Maynard et al. 1935, Taylor 1956*).

Deer provided an important source of meat and clothing for the Indians, and Indian activities (hunting, agricultural clearings, fires) probably had some effect on deer populations. However, their effect was undoubtedly small in comparison with that resulting from later settlement by Europeans.

Even the earliest settlers cut timber for market. It took muscle and horsepower to log in those days.



PHOTO FROM CHARLES CATLIN COLLECTION



Early steam-powered circular sawmills in Warren County; (above) Bucher's Mill at the present site of Chapman Dam State Park, and (below) Wood's Mill at the present site of the Farnsworth Fish Hatchery. The first water-powered sawmill in the county was established in 1800.

PHOTOS FROM WARREN COUNTY HISTORICAL SOCIETY



## Settlement and Development

Several early explorers apparently passed down the Allegheny River during the 1600s and early 1700s, but the first fully documented exploration in the region that is now the Allegheny National Forest was that of Captain Bienville de Celeron, who came down Conewango Creek to the Allegheny River with a party of 215 Frenchmen and 55 Indians in 1749. Nearly 40 years passed before Fort Franklin was garrisoned in Warren County in 1787, and it was not until 1796-97 that the first white settlers arrived (*Kussart 1938, Schenck and Rann 1887*).

Settlement proceeded slowly during the next 10 or 20 years. The three major routes of travel across the Alleghenies from the East Coast to the western frontier (then in Ohio) were all to the south, the northernmost route passing through what is now Kittanning.

Although the Allegheny River was also an important travel route, serving primarily as a way for settlers crossing from New York State to reach the Ohio Valley, few of these settlers stopped on the Allegheny Plateau. The rough topography and climate prevented heavy settlement for farming (*Mason 1936*). As a result, the population of Warren County was only 26 in 1810 (*Schenck and Rann 1887*), and that of McKean County was only 142 in that same year (*Bennett 1969*).

Early settlers cleared the forests for their cabins and for a limited amount of agriculture. To the crops of corn, beans, pumpkins, squash, and other vegetables they got from the Indians, they added wheat and oats, and later sheep for both meat and clothing (*Mason 1936*).

Even the earliest settlers did some timber cutting for market: the first sawmill in Warren County was established in 1880 (*Illick 1922*). This was a water-powered mill, with an overshot wheel, built in conjunction with a grist mill. About 30,000 feet of pine timbers from this mill were rafted to Pittsburgh in 1801; this was probably the first lumber raft to be sent down the Allegheny (*Kussart 1938*).

## Rafting on the Allegheny

The Allegheny River was declared a public thoroughfare in 1807, primarily for rafting of lumber, but also for freight on flatboats. The first roads were built through the valleys about 1810 (*Mason 1936*). With the roads and river transport came more people. Warren County was organized as an official entity in 1819, at which time its population had grown to nearly 2,000 (*Schenck and Rann 1887*).

The first steamboat cruised on the upper Allegheny River in 1830, by which time the population of Warren County had reached 4,697. Although steamboat service was always sporadic (upper parts of the river were passable only during high water; so boats often made only one or two rounds trips a season), it was a great improvement over hand-poled or horse-drawn keel boats, which often required 10 to 12 days to make the journey from Pittsburgh with their limited cargos. By 1840, the population of Warren County had doubled again, to 9,278 (*Schenck and Rann 1887*).

From a modest beginning in 1801, lumbering and rafting increased rapidly. Pine from the Brokenstraw, Conewango, Kinzua, Tionesta, and Allegheny Valleys was sawed on the many water-powered mills that sprang up after 1820.

About 1820, it was estimated that there were 15 sawmills on Brokenstraw Creek, producing 9 million feet annually; 30 sawmills on Conewango Creek, producing 18 million feet annually (*Kussart 1938*); and 21 sawmills on Tionesta Creek (*Lutz 1930b*).

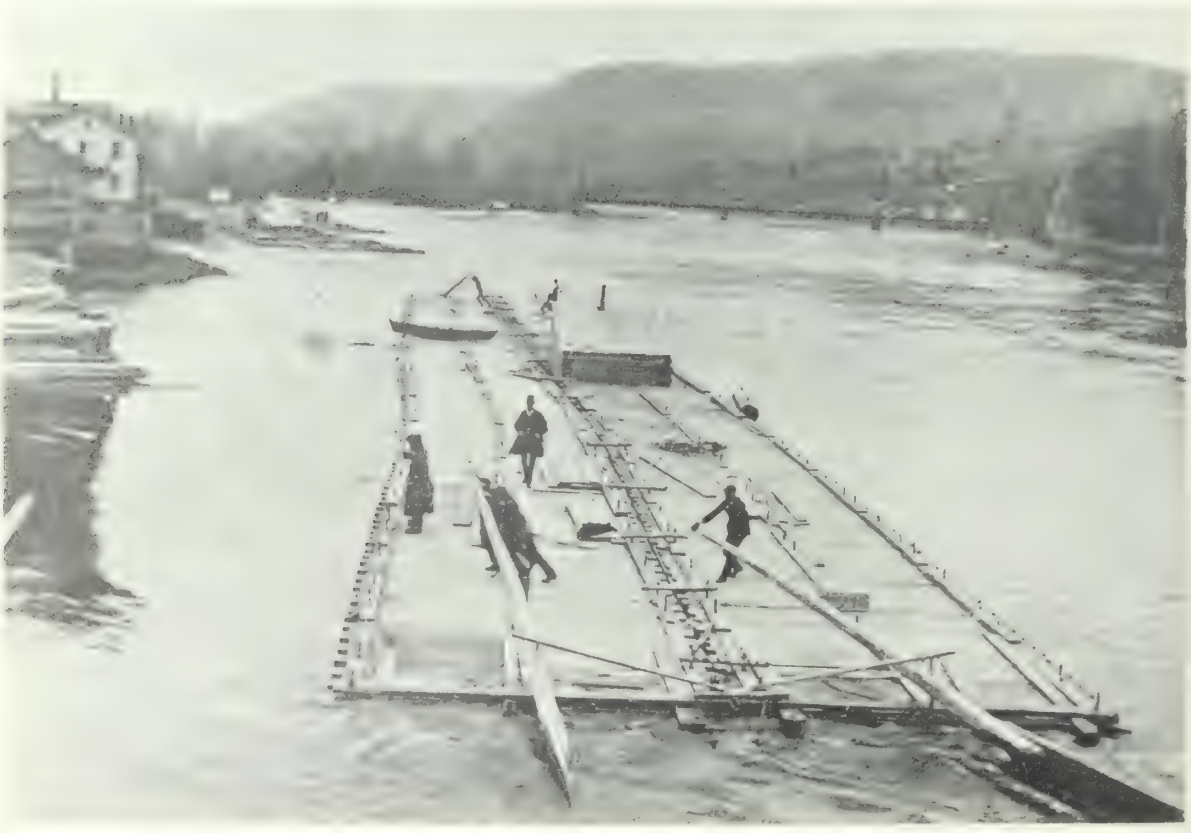
By 1837, there were an estimated 100 sawmills in Warren County, producing 45 miilion feet annually (*Kussart 1938*). This latter figure suggests that somewhere between 1,000 and, 2,000 acres of pine timber must have been harvested in Warren County each year during this period. Timber harvesting was of considerable importance even in these early times.

Although there is no way of knowing, these lumber production figures may be somewhat exaggerated. It was common practice in those days to speak of a mill in terms of its rated capacity—actual cut was usually much less than this. In view of the population in 1820, the quoted production figures seem high.



Rafting became big business in the early 1800s. Great rafts like these at Warren carried Allegheny Plateau lumber to Pittsburgh, to Cincinnati, and even to New Orleans.

PHOTOS FROM WARREN COUNTY HISTORICAL SOCIETY



Records of the amount of lumber reaching Pittsburgh via Allegheny River rafts provide another crude index of the lumber industry on the upper river. From an average of about 3 million feet annually before 1810, the amount of lumber rafted to Pittsburgh increased to 7 million in 1812, and to 20 or 30 million in 1860 (*Kussart 1938*). In 1840, common pine boards sold for $7 per thousand while, clear boards brought $14 per thousand.

Early accounts of lumber rafts provided a vivid picture of their size and importance. One writer suggested that the principal streams were filled with rafts of lumber each spring, waiting for high water to carry them to Pittsburgh or Cincinnati or even New Orleans.

At Warren, groups of 30 rafts were united into a fleet, each propelled by six oars, with one man per oar (*Mason 1936*). Some of these rafts were 60 to 70 feet wide and 250 to 300 feet long (*Kussart 1938*). The largest single raft was said to have contained 1,500,000 feet of lumber and to have covered over 2 acres of water surface (*Schenck and Rann 1887*).

In spite of lumbering operations, the Allegheny Plateau remained a heavily forested inaccessible frontier area through 1850 or 1860. The effect of lumbering was still noticeable only along the larger streams; vast amounts of pine remained untouched along the smaller streams (*Kussart 1938*). And those areas somewhat removed from the Allegheny River itself were much slower to develop.

For example, Warren County was settled about 1800 and McKean County about 1804, but Elk and Forest Counties were not formed until 1843 and 1848. The first settlers in Warren Township came before 1800, but Tionesta was not settled until 1816, and Oil City not until 1824 (*Kussart 1938*).

## Industrial Development

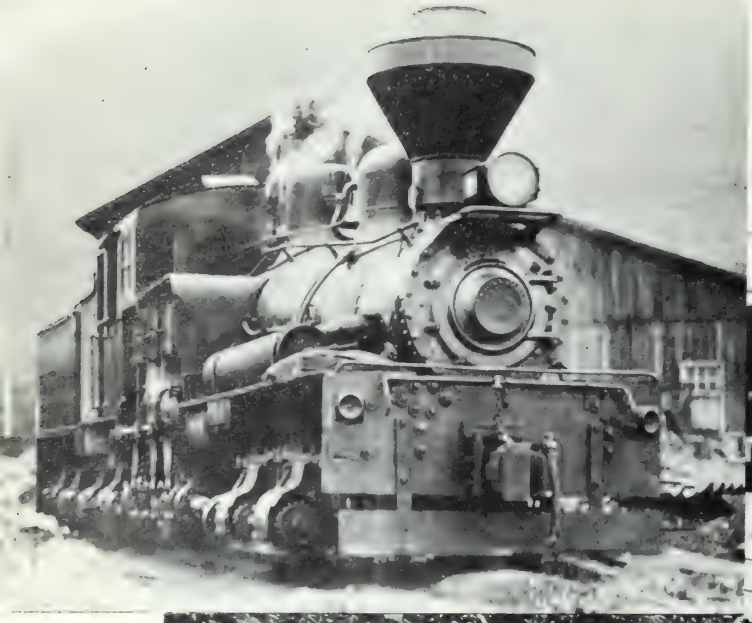
However, by 1860 the pioneer character of the Plateau region had begun to give way to industrial development. Steam provided the power for most of this industrialization, in the form of steam railroads, steam-powered saw-

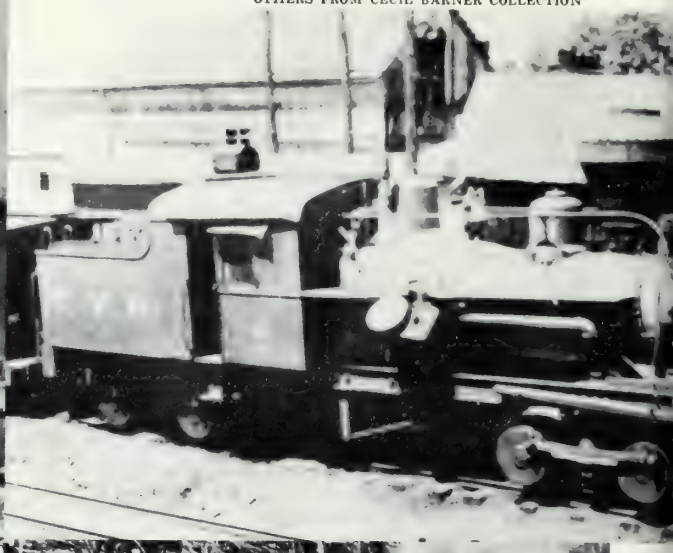
Industrialization came to the Allegheny Plateau in mid-century. The first railroad reached Warren in 1859, and the first oil well was drilled the same year. This is how Warren looked at the peak of the oil boom.



PHOTO FROM WARREN COUNTY HISTORICAL SOCIETY

HEISLER PHOTO FROM WARREN COUNTY HISTORICAL SOCIETY
OTHERS FROM CECIL BARNER COLLECTION










The heyday of logging began in the late 1800s, when special steam locomotives were developed for logging. These geared locomotives were: the Shay (upper left), the Heisler (upper right) and the Climax (center and bottom).

mills, steam log loaders, and other similar equipment. The first railroad was completed to Warren in 1859, and two others were opened within the next 10 years.

The first oil well was drilled in 1859, and the Tidioute oil field was opened in 1860. By 1880-90 the oil industry had reached peak production of over 30 million barrels annually (*Schenck and Rann 1887*).

Tanneries appeared in the 1850s, and circular sawmills began to replace the water mills during the 1860s (*Bennett 1969*). Huge bandsaw mills with rated capacities of 30 to 40 million feet annually (actual cut about 10 to 20 million feet annually) appeared after 1870 or 1880.

Locomotives especially designed for logging railroads (Shay, Climax, and Heisler locomotives) came into common use after 1885, and railroads were soon pushed up every drainage to tap the timber resources there. Chemical-wood plants began to appear about 1890.

The iron industry also influenced industrialization to a large extent. In 1849, for example, there were 504 blast furnaces in Pennsylvania using charcoal, of which one-third were in western Pennsylvania. Although charcoal was replaced by anthracite about 1855, anthracite was itself replaced by bituminous coal coke around 1875. This resulted in an 80-fold increase in bituminous coal production between 1847 and 1900, creating new drains on the forests for pit props, mine ties, and timbers (*Spring 1906*). Although the coal-mining and iron industries were concentrated south of the Allegheny Plateau region, both activities had some impact on the Allegheny forests.

## Early Cutting Was Patchy

As populations increased and industrial demands for land and raw materials expanded, the intensity of forest cutting accelerated. Pine continued to be the major species cut, but hemlock was also being felled after about 1850. Hemlock bark was widely used for tanning leather; and as pine began to become scarce, the amount of hemlock sawed into lumber increased dramatically.

Figures on pine and hemlock logs passing through the big boom at Williamsport provide some measure of the changes that occurred. In 1875, ten times as much pine passed through the boom as hemlock (190 vs. 20 million feet); but by 1893 the figures were nearly reversed: 33 million feet of pine vs. 187 million feet of hemlock (*Rothrock and Shunk 1895*).

Up until about 1880, forest cutting on the Allegheny Plateau was characterized by patchiness—small stands of pine here and there were harvested, scattered groups of pine throughout the remainder of the area, and some small proportion of the hemlock along the major drainages.

But the major portion of the virgin forest was still intact, although some cutting had occurred throughout. Most of the heavy cutting had been restricted to the stream valleys by the necessity of water transport for the logs.

## The Clearcutting Era

After 1880 to 1890, however, the development of logging railroads with their specialized locomotives and other equipment provided means of transporting logs from even the most rugged areas. There was no longer any need to rely on access to streams; railroads could reach anywhere, and they provided supplies of logs year-round.

The big band mills, too, made possible the large operations necessary to finance the building of railroads into the timber; and the chemical-wood industry provided a market for virtually every size and species of tree growing on the Plateau. It was no longer necessary to search out small pockets of pine, or to cut the hemlock and leave the hardwoods.

Nearly everything was merchantable: hemlock bark for tanning; logs for construction lumber, railroad ties, shingles, barrel staves, lath, furniture, tool handles, and other products; bolts for chemical wood to make charcoal, acetic acid, wood alcohol, and other distillation products; scrap pieces for clothespins and other speciality products; and slabs, edgings, and sawdust for fuel for homes and power.

Between 1890 and 1920, the virgin and partially cut forests were almost completely clearcut in what must have been the highest degree of forest utilization that the world has ever seen in any commercial lumbering area (*Horst and Smith 1969, Taber et al. 1970-72*).

Text continues on page 23

Railroads could reach up into any valley to bring the logs out.

A Barnhart log loader at work in the woods on the Goodyear Lumber Company operations, near Norwich about 1912.

PHOTO FROM CHARLES CATLIN C

PHOTO FROM CECIL BARNER COLLECTION



A loader crew of the Central Pennsylvania Lumber Company stand by to have their picture taken, near Masten in Lycoming County.

Potter's logging camp on the east branch of Tionesta Creek in 1933.

Mess hall of Potter's logging camp.

PHOTO FROM JAMES SCHMONSKY COLLECTION

Though the logging railroad opened the way into the woods, it still took a lot of manpower and horsepower to fell the trees and get the logs to the landing. A scene at a logging camp near Cherry Grove in Warren County.

PHOTO FROM CHARLES CATLIN COLLECTION



A log and bark landing on the Potato Creek Railroad of the Goodyear Lumber Company about 1912. Notice the chute for sliding hemlock bark down the hillside.



And didn't they bring in the logs!







LOWER PHOTO FROM COLLECTION
OF DELBERT SILVES



Trainload by trainload, the logs move toward the mill.



Great band sawmills sprang up after about 1890, to produce billions of board feet of lumber. Central Pennsylvania Lumber Company sawmill at Sheffield in Warren County.





Tanneries provided a big market for hemlock bark. Hemlocks in the top photo have been felled and peeled; notice the pile of bark in left foreground. In the bottom photo, sawyers are bucking a peeled hemlock log. Notice that the butt of the hemlock in the left background has been peeled before felling.

A trainload of hemlock tanbark on Central Pennsylvania Lumber Company operations in McKean County.

Elk Tanning Company Plant in Wilcox. Notice large pile of hemlock bark in right center.





Bolts of chemical wood used for making charcoal, acetic acid, alcohol, and other distillation products at the Otto Chemical Company in Sergeant, McKean County.




Scenes from the Union Charcoal Company chemical wood plant at Westline in McKean County.

## Market for Deer

Lumber was not the only forest product used during this era: deer were hunted extensively. The extent of this hunting pressure during early times is probably not fully appreciated today. There were no closed seasons or restrictions on the number that could be taken. Professional hunters shot deer for the market, using dogs and salt licks to increase their efficiency. The demand for deer meat for hotels, lumber camps, and city markets was extreme.

For example, in Michigan, where extensive cutting was also taking place, more than 100,000 deer were sold in the markets in 1880 (*Taylor 1956*). The situation in Pennsylvania was probably similar.

## Effect of Lumbering on Seedling Regeneration

As we have seen, the forests of the Allegheny Plateau were subjected to two distinctly different types of cutting. From 1800 to 1890, lumbering involved scattered, sporadic harvesting of the larger trees of selected species. The vast majority of trees cut during this period were white pine, although hemlock and even some of the better hardwoods were cut toward the end of the period.

Then, from about 1890 to 1920 (and in some areas up to 1930), the areas that had been partially cut, and areas that had never been cut, were completely cleared. Most of the Allegheny Plateau was clearcut during that

The slash left in logging operations provided plenty of fuel for fires, particularly in areas where coniferous trees were abundant.





Smoke from the fire at Bear Creek in the Owl's Nest area of Elk County, in May 1926.

30- to 40-year period, and the present forests originated at that time.

Forest fires were extremely common during this latter era in areas that had originally contained conifers, and fires had a major effect on the present forest areas. In 1908, a million acres of forest land were burned in Pennsylvania (*Banks 1960*), as opposed to a current average of less than 8,000 acres (7,776 acres average in 1970-72).

Heavy cutting tends to favor hardwoods, since small hardwood seedlings that often exist beneath a forest canopy (advance seedlings) have a head start on new pine seedlings and can outgrow any hemlock advance seedlings. In addition, the frequent and repeated fires are much more damaging to coniferous seedlings than to hardwood seedlings, because the latter have the ability to resprout.

Thus fires probably were a major factor in the virtual elimination of white pine and hemlock in the Allegheny forests (*Illick and Frontz 1928, Bennett 1969*).

The massive amounts of coniferous slash provided ideal conditions for widespread and intense fires. Some fires burned in hemlock slashings for weeks at a time during the 1895-1930 period (*Mason 1936*). Repeated or se-

vere fires also tended to reduce the proportions of sugar maple, beech, and other typical hardwoods, and to increase species such as aspen, pin cherry, bracken fern, goldenrod, blackberry, sedges, grasses, and honeysuckles.

In some places, fires burned intensely enough to remove all humus, exposing the clay soil and creating some of the numerous open-areas that are still present on the Plateau, such as the Owl's Nest area (*Stotz 1957*, *Hough 1958*).

However, if fires were kept out or were not too severe, the second-growth stands that followed clearcutting were very acceptable. Many had produced 1 cord per acre per year by age 30 (*Elliott 1927*, *Illick and Frontz 1928*). They developed into the well-stocked pole stands noted by Ostrom (*1938*) and Hough and Forbes (*1943*), and are plainly evident today in the many small sawtimber stands of excellent species composition–stands dominated by black cherry, red maple, sugar maple, and white ash.

A scene today from the area burned in the Mill Creek fire of 1925; not much here but a few scattered trees and a savannah-type ground cover of bracken fern, goldenrod, aster, and grasses.



## Protecting the Deer

By 1890, market hunting had made deer so scarce that they were rarely seen in their native habitat, and such sightings as did occur rated front page coverage in the local newspaper (*Clepper 1931*).

However, public concern for deer eventually led to an increase in deer populations. Pennsylvania appointed a game commission in 1896. Salt licks and dogs were forbidden for deer hunting in 1897, and market hunting was prohibited after about 1900. Game refuges were established beginning in 1905, and in 1906 deer were imported from other states to restock depleted areas. Perhaps most important of all, beginning in 1907, hunting was restricted to bucks (*McCain 1941*, *Leopold 1943*, *Roberts 1962*).

At about the same time that laws protecting deer were being enacted, extensive timber harvesting was providing increasing amounts of browse for the deer to feed upon. With predators eliminated, palatable browse accumulating in recently clearcut areas, and complete protection of does from hunting, the deer population was definitely on its way to an irruption.

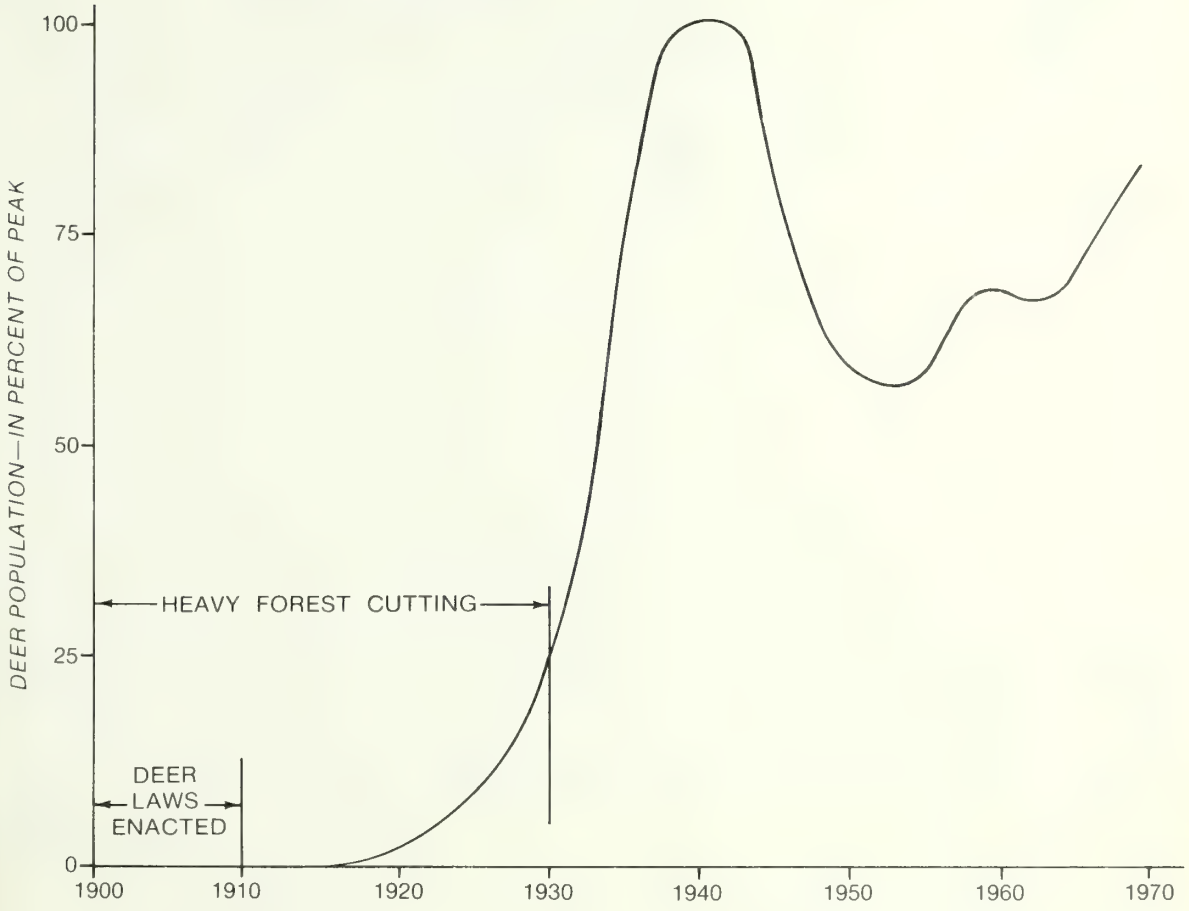
As early as 1917, a few biologists began to warn that the deer population would soon be too large unless measures were taken to reduce further increases. The warnings were ignored. By 1922, deer were causing serious damage to agricultural crops and forest reproduction. In 1923, new laws permitted farmers to kill deer of either sex at any time of the year if they were damaging crops, and the state began providing free materials to farmers who wanted to fence their crop lands (*Leopold 1945*, *Winecoff 1930*).

Attempts to permit hunting of does began in 1923, but they were successfully boycotted or stopped by court injunctions obtained by sportsmen. Professional hunters were employed in 1927 in a futile attempt to reduce population levels in several critical regions. Fi-

Because of the changes in forest conditions, the deer population exploded. Now severe overbrowsing by deer hinders forest regeneration.



The deer populations in Pennsylvania from 1900 to 1970. Adapted from Leopold (1943), Bennett (1957), and records of Pennsylvania deer harvests.




nally, in 1928, the first statewide doe season was held.

Large deer kills (as high as 186,575 in 1940) during the seasons of 1931, 1938, and 1940 checked the deer irruption and eventually brought the deer populations down from their peak levels, but not before severe overbrowsing had occurred. Vegetation less than 6 feet tall was completely eliminated in many areas, and available food supplies were badly depleted (*Leopold 1943, Winecoff 1930*).

## Too Many Deer

During the 1930s, the last of the young second-growth forests were rapidly growing out of reach of the deer and into the small pole stage. Winter browse became extremely limited. Hunters began complaining about the small size of the deer and their thin unattractive antlers. Fishermen were shocked at finding hundreds of decaying deer carcasses along trout streams in the spring. During the winter of 1935-36, an estimated 40,000 deer died of starvation (*McCain 1941*).

Winter conditions were especially harsh due to the lack of protective cover resulting from the widespread clearcutting (*Maynard et al. 1935*). Occasional doe seasons and continued winter mortality eventually brought the herd down to half of its peak level.

During the peak years, local populations as dense as one deer on 5 to 6 acres were believed to be common. On study plots established by the Pennsylvania Department of Forests and Waters, every woody plant less than 6 feet tall



An experimental deer exclosure on the Pocono Experimental Forest. The area left of the fence has been browsed bare. Inside the fence, to the right, an abundance of seedlings have got a start.

had been completely destroyed or hopelessly injured at these densities. Tree planting had to be suspended in many localities, and continued clearcutting under such conditions would almost certainly have resulted in the elimination of tree growth (*Frontz 1930*).

By the early 1950s, deer populations in the state leveled off, then began increasing again in the 1960s. In the heavily forested northern Allegheny Plateau, damage to tree reproduction continues, and small deer size persists.

Evidence of a continued overpopulation is found in deer-browse consumption data collected on northeastern national forests. Twig-browse utilization is 3 to 10 times greater on the Allegheny than on the six other eastern national forests, and twig production has been reduced 2 to 3 times by overutilization (*Stiteler and Shaw 1966*).

Thus deer were not a factor when the present forests were being formed. Deer populations in 1900 were less than one one-hundredth of those at present. By 1920, when most of the clearcutting of Allegheny Plateau forests was complete, deer populations were still about one-third the size of those at present.

## Current Conditions

The second-growth forests that originated after the clearcuttings of 1890-1920 are now 50 to 80 years old. Trees in the older stands are large enough to be valuable for timber. Wood-using industries declined greatly on the Allegheny Plateau after the original forest had been cleared, but began to increase again 10 to 15 years ago. As Allegheny hardwood forests reach maturity, they are again being harvested.

But things are much different this time.

Much of our forest land is now under some

One of the most valuable species on the Allegheny Plateau is black cherry. The man shown by this fine specimen is the late Ashbel F. Hough, who spent most of his career as a research forester studying the ecology and silviculture of black cherry and other Allegheny hardwoods.



sort of sustained-yield management. We have insured this by setting large acreages aside in our national and state forests, where cutting is carefully regulated and integrated with all of the other important uses.

Sustained yield is no less assured on the land owned by the wood-using industries, for their forests are their source of raw materials; and these lands too are managed under sound forestry principles to provide continuing supplies of timber for the owner's mills. So timber cutting will never return to the "cut-and-get-out" type of operation that saw the entire region cut over within a 30- to 40-year period.

## Still Problems

Nevertheless, there are still some problems associated with the current cuttings. Considerable difficulty is being encountered in obtaining prompt regeneration after the mature trees have been removed. Instead of vigorous new seedling regrowth, such as occurred after the 1890-1920 cuttings, the areas sometimes regenerate to only a few trees, often of undesirable species—or to ferns, grasses, goldenrod, and similar vegetation.

The difficulty may be attributed to several factors.

First, the second-growth stands of today often lack advance regeneration—the understory of seedlings that sometimes occurs beneath mature trees. Advance regeneration was more abundant under the original forests, a natural consequence of their overmature condition, and was probably stimulated by the partial cuttings during the period before 1890. But the second-growth stands of today have not had the benefit of widespread partial cutting, nor are they old enough for natural mortality to provide openings in the canopy to stimulate understory seedling growth.

A second reason for the current difficulty lies in the large deer population of today. Deer feed heavily on woody twigs—especially during winter when other food is scarce. They suppress and destroy advance regeneration as well as new seedlings that develop after cutting. Where deer populations are large, they can prevent successful seedling regeneration from developing.

Foresters are well aware of the current problems and have taken steps to limit cuttings to stands that have good chances for successful regeneration—those that have adequate advance regeneration. Much research is under way to find ways of increasing advance regeneration, of protecting seedlings from deer, and of establishing new stands through seeding or planting so that our Allegheny hardwood forests will continue to provide all of the many goods and services we have come to expect from them.



A second-growth stand of Allegheny hardwoods today. One problem in regenerating these stands is the lack of advance regeneration—the understory of seedlings that are needed to grow up to become the new forest.



The hemlock trees in this early stand have been cut and the canopy openings thus created have permitted development of a good understory of advance regeneration. When this stand was later clearcut, a valuable second-growth forest quickly developed on the site.

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This article describes the changes that have occurred in the Allegheny hardwood forests of northwestern Pennsylvania from the days of the Indian through the era of white settlement and industrial development up to the present time. Both the problems now faced in regenerating new stands and the bounty of timber and deer now obtained from these forests had their origin in events that occurred many years ago.

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# Summaries of Some SILVICAL CHARACTERISTICS of SEVERAL APPALACHIAN HARDWOOD TREES

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by George R. Trimble, Jr.

USDA FOREST SERVICE GENERAL TECHNICAL REPORT NE-16
1975
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

## The Author

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Common and scientific names of species referred to:

TREES

| | |
|---|---|
| Alder, smooth | *Alnus serrulata* (Ait. Willd.) |
| Ash, white | *Fraxinus americana* L. |
| Aspen, bigtooth | *Populus grandidentata* Michx. |
| Basswood | *Tilia americana* L. |
| Beech, American | *Fagus grandifolia* Ehrh. |
| Birch, yellow | *Betula alleghaniensis* Britton |
| Birch, sweet (black) | *Betula lenta* L. |
| Butternut | *Juglans cinerea* L. |
| Chestnut, American | *Castanea dentata* (Marsh.) Borkh. |
| Cherry, black | *Prunus serotina* Ehrh. |
| Cherry, pin (fire) | *Prunus pensylvanica* L. f. |
| Cucumbertree | *Magnolia acuminata* L. |
| Dogwood, flowering | *Cornus florida* L. |
| Elm, slippery | *Ulmus rubra* Muhl. |
| Gum, black | *Nyssa sylvatica* Marsh. |
| Hickory | *Carya* spp. |
| Hophornbeam, eastern | *Ostrya virginiana* (Mill) K. Koch |
| Locust, black | *Robinia pseudoacacia* L. |
| Magnolia, Fraser | *Magnolia fraseri* Walt. |
| Maple, red | *Acer rubrum* L. |
| Maple, striped | *Acer pensylvanicum* L. |
| Maple, sugar | *Acer saccharum* Marsh. |
| Oak, black | *Quercus velutina* Lam. |
| Oak, chestnut | *Quercus prinus* L. |
| Oak, northern red | *Quercus rubra* L. |
| Oak, scarlet | *Quercus coccinea* Muenchh. |
| Oak, white | *Quercus alba* L. |
| Sassafras | *Sassafras albidum* (Nutt.) Nees. |
| Serviceberry, downy | *Amelanchier arborea* (Michx. f.) Fern. |
| Sourwood | *Oxydendrum arboreum* (L.) DC |
| Sycamore, American | *Platanus occidentalis* L. |
| Yellow-poplar | *Liriodendron tulipifera* L. |
| Walnut, black | *Juglans nigra* L. |
| Willow | *Salix* spp. |

SHRUBS AND VINES

| | |
|---|---|
| Hawthorn | *Crataegus* spp. |
| Witch hazel | *Hamamelis virginia* L. |

# Summaries of Some SILVICAL CHARACTERISTICS of SEVERAL APPALACHIAN HARDWOOD TREES

by George R. Trimble, Jr.

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## ABSTRACT

A number of Appalachian hardwood trees are ranked according to the following silvical characteristics: shade tolerance, development of epicormic branching, susceptibility to frost damage, diameter growth rate, and seed dormancy.


MANUSCRIPT RECEIVED FOR PUBLICATION 6 JUNE 1974

## Introduction

THIS PAPER is an attempt to summarize under one cover some of the information available about several silvical characteristics of a number of hardwood species. Much of this information has been published previously piecemeal in a number of publications. Little of the material is original, but some new syntheses have been made.

Most of the tree species mentioned are common to the Central Appalachians, and much of the research on which the data were based was done in this area.

## Shade Tolerance

Shade tolerance means the capacity of tree seeds to germinate and of the trees to live, develop, and grow under canopies of varying densities. No attempt is made here to explain the physiological processes involved, nor to correlate degrees of shade tolerance with percentages of full sunlight. Such discussions are beyond the scope of this paper. For a basic understanding of tolerance, the reader is referred to *Forest Ecology* by Spurr *(1964)*.

However, it is pertinent to state, following Baker *(1950)*, that the tolerance of a given species is known to vary. Young trees are more tolerant than old trees; trees growing on moist, rich soils seem to be more tolerant than the average of the species; and tolerance seems to be greater in the southern part of the range of a tree.

A number of tolerance tables have been developed by foresters for different physiographic regions. These are found in standard textbooks, bulletins, and the *Forestry Handbook (Forbes 1961)*. The considerable differences that often exist between the tables in tolerance ratings for the same species are probably largely the result of two things: (1) real differences in tolerance within species due to different environmental conditions; and (2) the fact that a standardized method for making objective ratings has never been adopted–species have generally been ranked subjectively.

In my opinion, the following table (table 1) is generally applicable to Central Appalachian conditions. It is a modified version of a table by Baker *(1950)*, and was used in *The Regeneration of Central Appalachian Hardwoods with Emphasis on the Effects of Site Quality and Harvesting Practice (Trimble 1973)*.

## Epicormic Branching

Epicormic branches arise from dormant buds or sometimes from adventitious buds; or as Kormanik and Brown *(1969)* prefer to call them, inhibited and suppressed buds. For a detailed understanding of the physiology of the development of branches from these buds, the reader is referred to *Origin and Development of Epicormic Branches in Sweetgum (Kormanik and Brown 1969)*. It suffices to state here that the development of epicormic branches is generally triggered by injury to the tree itself or by exposing it to additional light by cutting surrounding stems.

Because they degrade lumber quality, epicormic branches have been much studied. Based on work done on the Fernow Experimental Forest (an outdoor laboratory of the Northeastern Forest Experiment Station, USDA Forest Service) near Parsons, West Virginia, table 2 was developed for ranking 12 hardwood species in their susceptibility to epicormic branching. The table resulted from studies by Smith *(1966)* and Trimble and Seegrist *(1973)*.

Table 1.—Tolerance ratings[a]

| Species | Tolerance rating | | | | |
|---|---|---|---|---|---|
| | Very tolerant | Tolerant | Intermediate | Intolerant | Very intolerant |
| Eastern hophornbeam | X | | | | |
| American beech | X | | | | |
| Sugar maple | X | | | | |
| Flowering dogwood | X | | | | |
| Red maple | | X | | | |
| Basswood | | X | | | |
| Black gum | | X | | | |
| Sweet birch | | X[b] | | | |
| Fraser magnolia | | | X[c] | | |
| Cucumbertree | | | X[c] | | |
| White ash | | | X | | |
| Basswood | | | X[b] | | |
| Black gum | | | X[b] | | |
| Yellow birch | | | X | | |
| Sweet birch | | | X | | |
| White oak | | | X | | |
| Northern red oak | | | X | | |
| Black oak | | | X | | |
| Chestnut oak | | | X[d] | | |
| Slippery elm | | | X[b] | | |
| Hickories | | | X[b] | | |
| Downy serviceberry | | | X[b] | | |
| Sourwood | | | X[b] | | |
| Scarlet oak | | | | X[d] | |
| Butternut | | | | X | |
| Hickories | | | | X | |
| Yellow-poplar | | | | X | |
| Sassafras | | | | X[c] | |
| Black cherry | | | | X | |
| Bigtooth aspen | | | | | X |
| Black locust | | | | | X |
| Pin cherry | | | | | X[b] |

[a] From Baker (*1950*) unless otherwise noted.
[b] Local observation.
[c] Great uncertainty (from *Baker*).
[d] Silvics of Forest Trees of the United States (*USDA Forest Service 1965*).

Table 2.—Susceptibility to epicormic branching by species

| Number of branches | Species |
|---|---|
| Very many | White oak |
| | Northern red oak |
| Many | Basswood |
| | Black cherry |
| | Chestnut oak |
| Few | Beech |
| | Hickory |
| | Yellow-poplar |
| | Red maple |
| | Sugar maple |
| | Sweet birch |
| Very few | White ash |

## Susceptibility to Frost Damage

Differences among species in susceptibility to damage by spring frosts may have an effect on species composition of stands in certain areas. This phenomenon has been investigated and reported on by Tryon and True *(1964)*. With permission, their publication is quoted:

> Frosts may occur frequently in the Appalachian region, and spring frosts which occur after growth has started are especially damaging to forest trees. Such frosts deform stems, reduce growth rate, and may kill the smaller reproduction. . . . Trees of all sizes may be damaged, but the reproduction and saplings are usually

Table 3.—Species susceptibility to frost damage

| Highly susceptible[a] | Moderately susceptible | Less susceptible | Least susceptible |
|---|---|---|---|
| Sassafras | Fraser magnolia | Smooth alder | Slippery elm[b] |
| American sycamore | White ash[c] | Serviceberry | Willow[b] |
| Black locust | American chestnut | Witch-hazel | Flowering dogwood[b] |
| American beech | White oak | Striped maple | Hawthorn |
| Cucumbertree | Scarlet oak | Fire cherry | American basswood |
| Yellow-poplar | Chestnut oak | Red maple | Sugar maple |
| Hickory spp. | Northern red oak | | Black cherry |
| Black walnut | Yellow birch[c] | | |
| Butternut[a] | Black birch[b] | | |

[a]The most susceptible species are at the top, and the least susceptible are at the bottom within each susceptibility class.
[b]Based on few observations.
[c]Considerable variation in degree of damage.

most severely injured. The period of establishment is therefore critical.

They prepared a frost-susceptibility rating tabulation based on frost damage during the springs of 1961 and 1963. They examined tree species in 12 localities in northern and east-central West Virginia and rated the degree of damage by late frosts to the newly formed leaves and shoots (table 3).

## Diameter Growth

Different diameter growth rates characterize different species of trees, but the differences are not always consistent between physiographic regions, sites within the regions, tree ages, or degrees of competition (usually expressed by crown-dominance classes). And even within crown-dominance classes, basal-area density exerts an influence on growth rates. Thus to compare dbh growth rates between tree species requires careful control of many variables.

In an attempt to segregate some of the common Appalachian species by growth rates, six publications were examined that gave results of studies made in West Virginia, and two were reviewed that reported on studies made in northwest Pennsylvania. West Virginia references were: Trimble *(1960)*, Trimble *(1967)*, Trimble *(1968)*, Trimble and Mendel *(1969)*, Trimble *(1969)*, Mendel and Trimble *(1969)*. Pennsylvania references were: Grisez and Mendel *(1972)*, and Mendel, Grisez, and Trimble *(1973)*.

As a result of this review, the grouping of species was based largely on West Virginia conditions. Table 4 applies to medium-size sawtimber trees (about 15 to 20 inches dbh), and to dominant and codominant stems growing in reasonably well-stocked stands on good and better sites. Extrapolation of the tabular data beyond the specifications indicated should be done with care. For example, for saplings, black cherry has a dbh growth rate greater than either red oak or yellow-poplar growth rates. And among overtopped trees, sugar maple has a dbh growth rate greater than those of red oak, yellow-poplar, or black oak.

Table 4.—Relative dbh growth rates for 15- to 20-inch trees

| Growth rate | Species |
|---|---|
| Fast | Northern red oak |
| | Yellow-poplar |
| | Black oak |
| Medium | Black cherry |
| | Sugar maple |
| | Red maple |
| | Basswood |
| | White ash |
| Slow | Chestnut oak |
| | White oak |
| | Hickories |
| | Sweet birch |
| | Beech |

## Seed Dormancy

Seed dormancy refers to the number of winters after falling that seed remains viable in the forest floor. In recent years, especially since the advent of extensive clearcutting, the interest in length of natural dormancy has increased greatly. Table 5 has been compiled from a number of sources.

Table 5.—Natural seed dormancy of hardwood species

| Species | Number of winters seed remains viable |
|---|---|
| Ash, white | 3[a,b] |
| Aspen | 0 Germinates soon after early summer seedfall[c] |
| Basswood | 4[d] |
| Beech | 1[c] |
| Birch, sweet | 1 as far as known[d] |
| Birch, yellow | 1 or possibly 2[d] |
| Cherry, black | 3 plus[e] |
| Cherry, pin | Unknown, but many years |
| Gum, black | 1 as far as known[d] |
| Hackberry | 3[a] |
| Hickories | 1[d] |
| Locust, black | Unknown but probably several years. |
| Maple, red | 1, but much seed germinates shortly after falling in late spring.[c] |
| Maple, sugar | 2 possibly. Most germinates after first winter.[c] |
| Oak, black | 1[d] |
| Oak, chestnut | 0 probably. Germination is in fall after seed drop.[d] |
| Oak, Northern red | 1[d] |
| Oak, scarlet | 1[d] |
| Oak, white | 0 Germinates in fall after dropping.[d] |
| Sassafras | 3 plus[f] |
| Yellow-poplar | 8[g] |

[a]Clark (1962).
[b]Leak (1963).
[c]Leak, Solomon, and Filip (1969).
[d]U. S. Forest Service (1965).
[e]Wendel (1972).
[f]Unpublished information, Fernow Experimental Forest.
[g]Sander and Clark (1971).

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5 p. (USDA For. Serv. Gen. Tech. Rep. NE-16)

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# Spray-Irrigation of Treated Municipal Sewage Effluent and its Effect on Chemical Properties of Forest Soils

USDA FOREST SERVICE GENERAL TECHNICAL REPORT NE-17
1975
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

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## Abstract

The Waste Water Renovation and Conservation Project at The Pennsylvania State University was begun to determine the feasibility and effectiveness of land irrigation as a method of municipal sewage effluent disposal.

Irrigation was begun in 1963 on an old-field area, a hardwood stand, and a red pine plantation on Hublersburg silt loam soil. In 1965, irrigation was begun in a hardwood stand located on Morrison sandy loam soil on State Game Lands. The old-field area and game-land hardwood area received application at a rate of 2 inches per week, and the hardwood stand and red pine plantation 1 inch per week. The irrigation period for the old-field area, hardwood stand and red pine plantation was April through November, while the game-land hardwood area was irrigated year-round.

Soil samples were collected in the fall of 1963, 1967, and 1971. The samples were taken with a Veihmeyer tube by 1-foot depth increments to 5 feet. The soil samples were analyzed for potassium, calcium, magnesium, sodium, exchangeable hydrogen, manganese, boron, phosphorus, pH, total nitrogen, and organic matter. The differences in the amounts of the various elements were tested for significance, using a factorial analysis of variance.

Of the 11 constituents analyzed, only potassium, sodium, manganese, exchangeable hydrogen, boron, and phosphorus had significant changes in concentration over time. Potassium, manganese, exchangeable hydrogen, and boron decreased significantly over time while sodium and phosphorus increased significantly over time.

After 9 years of spray irrigation with treated municipal wastewater, there were no indications that the treatment had any detrimental effects on the soil.

# Spray-Irrigation of Treated Municipal Sewage Effluent and its Effect on Chemical Properties of Forest Soils

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## INTRODUCTION

As MAN'S population increases, more communities, towns, and cities are formed, creating a greater demand on the nation's water resources. Along with this increasing water demand comes a problem of increasing volumes of wastes. In the past, the nation's streams, rivers, and lakes have been used to dilute these wastes; but now the steadily increasing volume of wastes is exceeding the dilution ability of these waterways. When the waterways can no longer dilute the wastes satisfactorily, the increased concentration of wastes causes an increase in nutrient levels, which may result in excessive growth of algae and aquatic weeds. This excessive growth can upset the ecology of the ecosystem and reduce the aesthetic and recreational value of the body of water.

An alternative to disposing of wastes directly into waterways was investigated at The Pennsylvania State University. This method involved the use of an irrigation system to spray wastewater over croplands and in forested areas. It was hoped that by spraying the wastewater over the land areas, the soil would renovate and return most of the water to the underground reservoir, thus producing three important benefits: (1) the concentration of nutrients in the wastewater would be reduced by the biological, chemical, and physical processes in the soil; (2) the nutrients removed by the soil could be available to the vegetation growing on the irrigated areas; and (3) the renovated water could percolate down through the soil profile and could be used to recharge the groundwater.

The Waste Water Renovation and Conservation Project at The Pennsylvaia State University was begun in 1962. It was designed to determine whether land irrigation with wastewater is an effective and feasible method of wastewater disposal and if potential benefits such as wastewater renovation, vegetation fertilization, and groundwater recharge could be realized.

The study reported here is a part of the Waste Water Renovation and Conservation Project. It deals with the investigation of changes in the chemical properties of the soils in the forested areas as a result of irrigation with wastewater over a 9-year period.

A preliminary study of the changes in the chemical properties of soils in the forested irrigation areas was conducted on soils collected in 1963, 1964, and 1965. This was reported by Kline *(1967)*.

Since the wastewater, or sewage effluent, contains appreciable concentrations of nutrients, this study was designed to determine whether any significant buildup of nutrients at various depths in the treated forested areas has occurred as compared to the control areas, and to measure the change in element concentrations over time.

The study reported here is based on chemical analysis of the soils collected from the forested wastewater irrigation areas in 1963, 1967, and 1971 for 11 constituents—potassium, calcium, magnesium, sodium, exchangeable hydrogen, manganese, boron, organic matter, pH, total nitrogen, and phosphorus.

## DESCRIPTION OF STUDY AREA

### Location and Design

The sewage effluent irrigation study areas are located in compartment 19 of the University Farm Woodlands in Patton Township, Centre County, Pennsylvania, and in State Gamelands No. 176 (fig. 1).

The study areas on the University Farms consist of an old field, a natural hardwood stand, and a red pine plantation on a Hublersburg silt loam soil. The fourth area, in State Gamelands, was a natural hardwood stand on a Morrison sandy loam soil. Each cover type and soil site was delineated in treatment and control areas.

### Vegetative Cover Types

*Old-field area.*—The old field was once agricultural land, but was subsequently planted with white spruce. The spruce have since dwindled in numbers as a result of deer damage and theft of Christmas trees, and the area has been invaded by herbaceous vegetation and grasses. In 1963 the white spruce saplings ranged from 3 to 5 feet in height.

*Hardwood stand.*—The hardwood stand in the Hublersburg soil consists mainly of mixed oak species with dominant and codominant trees about 70 years old, 14 inches in diameter (dbh), and 75 feet in height.

*Red pine plantation.*—The red pine plantation was established in 1939 at a spacing of 8 x 8 feet on abandoned agricultural land. In 1963 the average tree height was 40 feet, and average diameter was 8 inches. The forest floor is completely covered with a 2-inch layer of pine needles, which is part of a mor humus. There is no ground vegetation except in a few isolated openings in the plantation.

*New Gameland Hardwood Area.* — This

Figure 1.—Map of study area.

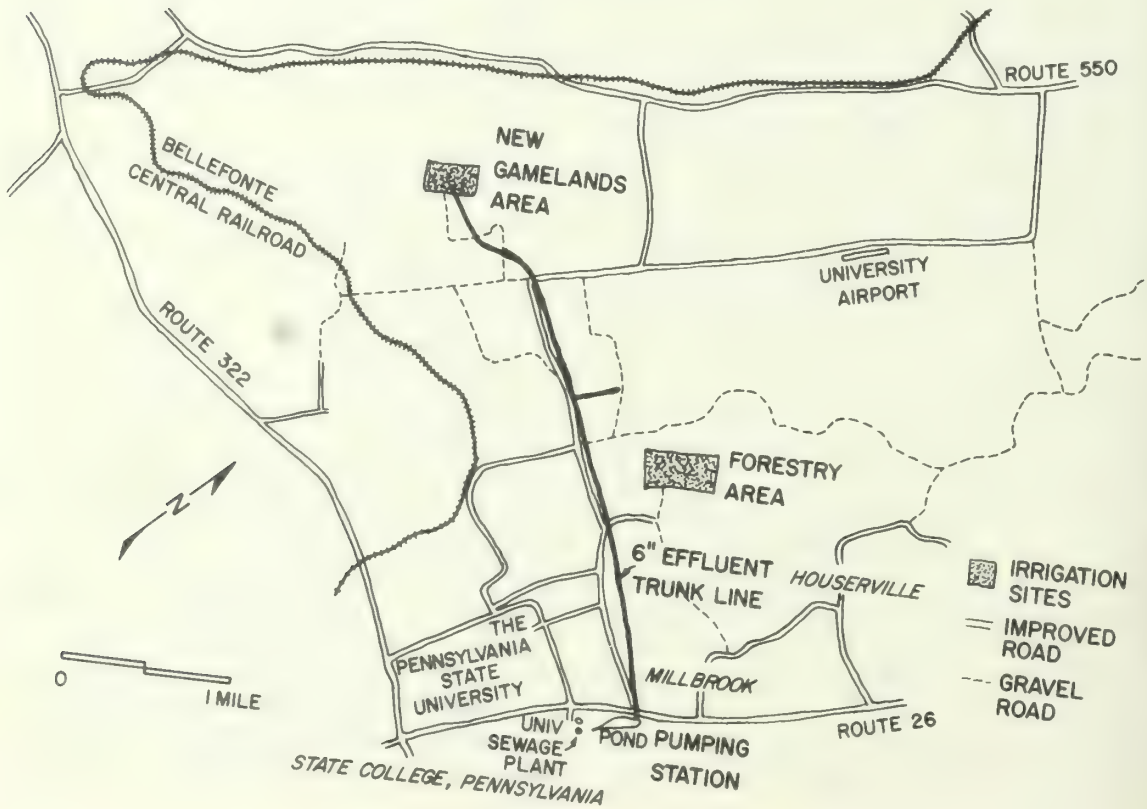


Table 1.—Major vegetation on study plots

| Common name | Scientific name |
|---|---|
| OLD FIELD — HUBLERSBURG SOIL | |
| Poverty grass | *Danthonia spicata* Beauv. |
| Goldenrod | *Solidago* spp. Ait. |
| Dewberry | *Rubus flagellaris* Willd. |
| White spruce | *Picea glauca* Moench. Voss. |
| HARDWOOD STAND — HUBLERSBURG SOIL | |
| Overstory: | |
| White oak | *Quercus alba* L. |
| Black oak | *Quercus velutina* L. |
| Red oak | *Quercus ruba* L. |
| Scarlet oak | *Quercus ruba* L. |
| Red maple | *Quercus coccinea* Muench. |
| Mockernut hickory | *Acer rubrum* L. |
| Black cherry | *Carya tomentosa* Nutt. |
| Flowering dogwood | *Cornus florida* L. |
| Understory: | |
| Black raspberry | *Rubus occidentalis* L. |
| Blueberry | *Vaccinium* supp. L. |
| Poison ivy | *Toxicodendron radicans* L. |
| Teaberry | *Gaultheria procumbens* L. |
| Violet | *Viola* spp. L. |
| Wild sarsaparilla | *Aralia nudicaulis* L. |
| RED PINE PLANTATION — HUBLERSBURG SOIL | |
| Red pine | *Pinus resinosa* Ait |
| NEW GAMELANDS HARDWOOD AREA — MORRISON SOIL | |
| Overstory: | |
| White oak | *Quercus alba* L. |
| Black oak | *Quercus velutina* L. |
| Red oak | *Quercus ruba* L. |
| Red maple | *Acer rubrum* L. |
| Black cherry | *Prunus serotina* Ehrh. |
| Flowering dogwood | *Cornus florida* L. |
| Understory: | |
| Black raspberry | *Rubus occidentalis* L. |
| Blueberry | *Vaccinium* spp. L. |
| Teaberry | *Gaultheria procumbens* L. |
| Violet | *Viola* spp. L. |
| Wild sarsaparilla | *Aralia nudicaulis* L. |

hardwood stand on the Morrison soil consists mainly of mixed oaks and red maple. The stand was about 50 years old in 1963. The height of the dominant and codominant trees averaged about 40 feet, and the diameter averaged about 8 inches.

Table 1 contains a list of all the major species found on the areas.

### Soils

The weathered mantle at the University Farm Woodlot is composed of beds of mixed clay, silt, and sand, which have accumulated as relatively insoluble residue from carbonate bedrock. The soil mantle ranges in depth from 17 to 48 feet. The unconfined water table is about 300 feet below the surface.

The soils at the old-field, hardwood, and red pine plots at the University Farm Woodlot are Hublersburg silt loam and silty clay loam derived from the Mines and Ore Hill members of the Gatesburg formation. The soil at the new gameland hardwood plot is Morrison sandy loam derived from the Upper and Lower Sandy members of the Gatesburg formation. The Morrison soil contains smaller amounts of clay, and the cation and anion exchange capacity are less than that of the Hublersburg soil.

A detailed description of the two soil series is included in the appendix.

### Climate

The study area is located at the western edge of the Ridge and Valley section of the Folded Appalachian Province. Elevation is approximately 1,100 feet.

The climate is characteristic of central Pennsylvania. It is a composite of the relatively dry midwestern continental climate and the more humid conditions found near the eastern seaboard. Minimum temperatures generally remain below freezing from mid-November through March, but only occasionally do temperatures drop below zero. The average date of the last 32° temperature in spring is 29 April and first in the fall is 12 October. Growing season is 166 days. Mean monthly temperatures range from 28.7°F in January to 72.1°F in July. Precipitation is well distributed throughout the year; average is close to 40 inches (U. S. Weather Bureau).

## DESCRIPTION OF SEWAGE EFFLUENT AND IRRIGATION SYSTEM

### Sewage Effluent

The sewage effluent used at the study area comes from The Pennsylvania State University sewage-treatment plant. This facility services both the University and the Borough of State College; it is made up of two parallel, two-stage treatment plants, each having a design capacity of 2 million gallons per

day. The plant employs both primary and secondary treatments. Secondary treatment consists of standard and high-rate trickling filters and a modified activated sludge process, followed by final settling and chlorination to a residual of 0.5 mg chlorine per liter. The chemical composition of the effluent varies from day to day. The typical chemical composition of the effluent is given in table 2.

The fertilizer value of the effluent is readily evident. The amount of N-P-K applied through spray irrigation of effluent at the rate of 2 inches per week during 1963-71 is given in table 3. The effluent applications annually provided commercial fertilizer constituents equivalent, on the average, to approximately 208 pounds of nitrogen, 200 pounds of phosphorus ($P_2O_5$), and 227 pounds of potash ($K_2O$). This would be equal to applying about 2,000 pounds of a 10-10-11 fertilizer annually.

### Irrigation System and Effluent Application

The pumping station that supplies effluent to the study area is located on a 24-inch bypass line. The station has two pumps, which are alternated manually, one acting as a standby. Each plant includes a vertical centrifugal pump, designed for an output of 350 gallons per minute at 520 feet total head, and a 60-horsepower three-phase electric motor. An in-line meter that measures the amount of effluent pumped is also located at the pumping station.

A 6-inch supply line carries the effluent a distance of 2 miles, where it divides. One 6-inch line carries effluent to the old field, hardwood, and red pine areas; the other 6-inch line carries effluent to the gamelands hardwod area.

The irrigation system is composed of 4- and 5-inch aluminum main lines and 2- and 3-inch aluminum lateral lines, which distribute the effluent to regularly spaced sprinklers on steel risers. With the use of special sprinkler heads, spacing of sprinklers on lateral lines, spacing of the lateral lines, and adjustment of the pressure at each lateral line, an application rate of ¼ inch per hour can be provided to all plots.

**Table 2.—Typical chemical composition of municipal sewage effluent**

| Constituent | Average concentration | Total amount applied[1] |
|---|---|---|
| pH | 7.9 | — |
| | *mg/l* | *lbs/a* |
| MBAS | 0.37 | 5.4 |
| Nitrate-N | 13.3 | 230.75 |
| Organic-N | 2.2 | 37.26 |
| $NH_4$-N | 6.9 | 110.30 |
| P | 4.90 | 81.68 |
| Ca | 31.3 | 536.41 |
| K | 12.3 | 201.32 |
| Cl | 41.3 | 711.20 |
| Mg | 15.1 | 257.14 |
| Na | 20.6 | 357.01 |
| Fe | .4 | 8.44 |
| | *µg/l* | |
| B | 169 | 2.89 |
| Mn | 61 | 1.04 |
| Cu | 109 | 1.75 |
| Zn | 211 | 3.72 |
| Cr | 23 | .38 |
| Pb | 104 | 1.89 |
| Cd | 9 | .17 |
| Co | 62 | 1.13 |
| Ni | 93 | 1.62 |

[1] Total amount applied during a 24-week irrigation period on areas that received 2 inches of effluent per week.

**Table 3.—Amount of N-P-K applied annually in the old-field Hublersburg site through spray irrigation of effluent**

| Irrigation period | Effluent applied | N | P | K |
|---|---|---|---|---|
| | *Inches* | *lbs/a* | *lbs/a* | *lbs/a* |
| 1963 | 46 | 119 | 54 | 127 |
| 1964 | 66 | 256 | 116 | 234 |
| 1965 | 60 | 139 | 122 | 199 |
| 1966 | 64 | 170 | 129 | 238 |
| 1967 | 56 | 157 | 98 | 176 |
| 1968 | 62 | 351 | 119 | 261 |
| 1969 | 56 | 275 | 66 | 175 |
| 1970 | 50 | 217 | 43 | 120 |
| 1971 | 55 | 184 | 40 | 174 |
| Mean | 57 | 208 | 87 | 189 |

[1] Applied at the rate of 2 inches per week.

A more detailed description of the irrigation system can be found in Parizek et al. *(1967)*, Pennypacker *(1964)*, and Sagmuller *(1965)*.

The treated plots within each vegetative cover type received a fixed amount of sewage effluent each week. The old field and game-

**Table 4.—Irrigation programs for treated plots**

| Location | Vegetative cover | Soil series[1] | Weekly application (inches) | Seasonal irrigation amounts, in inches | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1963 Jun-Dec | 1964 Mar-Nov | 1965 Apr-Nov | 1966 Apr-Nov | 1967 Apr-Nov | 1968 Apr-Nov | 1969 Apr-Nov | 1970 Apr-Nov | 1971 Apr-Nov | Total |
| Forestry area | Old field | H | 2 | 46 | 66 | 60 | 64 | 56 | 62 | 56 | 50 | 55 | 515 |
| Forestry area | Hardwood | H | 1 | 23 | 33 | 30 | 32 | 28 | 31 | 28 | 25 | 28 | 258 |
| Forestry area | Red pine | H | 1 | 23 | 33 | 30 | 32 | 28 | 31 | 28 | 25 | 28 | 258 |
| | | | | | | Nov 23 -Dec | Jan-Dec | Jan-Dec | Jan-Dec | Jan-Dec | Jan-Dec | Apr-Dec | |
| Gamelands area | New gameland hardwood | M | 2 | — | — | 12 | 104 | 104 | 102 | 104 | 90 | 79 | 595 |

H = Hublersburg silt loam.
M = Morrison sandy loam.

lands hardwood treated plots received 2 inches per week, and the hardwood and red pine plantation treated plots received 1 inch per week. The two weekly application rates were chosen because they are approximately and respectively equal to and double the average weekly precipitation in central Pennsylvania. A detailed description of the irrigation program can be found in table 4.

## METHODS AND PROCEDURES

### Soil-Sampling Technique

Each treatment and control plot within each vegetative type was divided into six subplots. A sampling point was located randomly within each subplot. Care was taken to avoid placing the sampling point in a natural depression, within 2 feet of a tree, or in an area where vegetation might prevent effluent from reaching the ground.

Soil sampling was performed with a Veihmeyer tube by 1-foot increments. Samples were taken to a depth of 5 feet and identified by the greatest depth sampled. For example, the 3-foot sample would consist of soil collected from 2.0 to 3.0 feet below the soil surface.

Twelve soil samples were taken at each depth from each vegetative type, at six positions in the treated plot and at six positions in the control plot. Soil samples were collected from the old-field 2-inch, hardwood 1-inch, and red pine 1-inch plots in 1963, 1967, and 1971. Soil samples were collected from the gameland hardwood 2-inch plot only in 1967 and 1971. All sampling was performed in the fall of the year after irrigation operations had terminated.

### Preparation of Soil Samples for Chemical Analysis

The soil samples were air-dried, crushed with a mortar and pestle, and passed through a 2-mm sieve. Large root fragments and pieces of chert and limestone were removed from the soil before crushing. Soil samples from only three randomly selected positions of the six positions sampled within each treatment and control plot were analyzed.

### Chemical Analysis

The exchangeable cations (K, Ca, Mg, Na, and Mn) and boron were extracted from the soil with ammonium acetate *(Jackson 1958)* and analyzed with an arc spectrometer *(Baker et al. 1964)*. Exchangeable hydrogen was determined by using a barium chloride buffering technique *(Jackson 1958)*. Organic matter was determined by using a potassium dichromate-sulfuric acid oxidation method *(Peach et al. 1947)*. Soil pH was measured with a glass electrode, using a 1:1 soil-to-water mixture. Total nitrogen was analyzed by using a modified Kjeldahl method to include nitrates *(Jackson 1958)*. The phosphorus concentration was determined by using the Bray extraction procedure *(Jackson 1958)*.

### Statistical Analysis

The differences in the concentrations of the various elements in the soil were tested for significance by using a factorial analysis of variance. The results were statistically analyzed to determine differences between treatments at various depths, between years, and between vegetative types.

The samples taken at various depths in the 1963, 1967, and 1971 control areas were compared to their respective treated areas to determine the effects of treatment. The changes at each depth were evaluated for the treated areas and for the control areas. Samples taken from the hardwood 1-inch treatment plot and red pine 1-inch treatment plot in 1963, 1967, and 1971 were compared to determine the difference in element concentration between vegetation cover types.

## RESULTS AND DISCUSSION

The mean concentrations of potassium, calcium, magnesium, sodium, exchangeable hydrogen, manganese, boron, organic matter, pH, total nitrogen, and phosphorus for all the soil samples collected in the old-field 2-inch plot, the hardwood 1-inch plot, and the red pine 1-inch plot in 1963, 1967, and 1971; and the gameland hardwood 2-inch plot in 1967 and 1971 are given in tables 5 through 15.

Text continues on page 10.

Table 5.—Mean constituent concentrations for the old-field 2-inch area in 1963

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.40 | 1.43 | 0.27 | 0.10 | 11.84 | 71.60 | 0.53 | 8.70 | 4.79 | 0.088 | 2.147 |
| | 2 | .47 | 2.00 | .83 | .17 | 8.67 | 20.46 | .60 | .76 | 5.23 | .016 | .370 |
| | 3 | .47 | 1.13 | 1.27 | .20 | 9.33 | 23.46 | .53 | .38 | 4.91 | .012 | .167 |
| | 4 | .43 | .93 | 1.57 | .20 | — | 18.60 | .53 | .38 | — | .010 | — |
| | 5 | .47 | .97 | 1.53 | .13 | — | 18.13 | .53 | .38 | — | .010 | — |
| Treatment ..... | 1 | .63 | 1.73 | .50 | .23 | 16.06 | 44.60 | 1.00 | 16.05 | 4.96 | .072 | 2.407 |
| | 2 | .60 | 1.87 | .90 | .20 | 18.74 | 20.80 | .80 | 1.48 | 4.68 | .022 | .390 |
| | 3 | .63 | 1.03 | 1.00 | .10 | 11.48 | 26.00 | .86 | .71 | 4.45 | .019 | .183 |
| | 4 | .53 | .77 | .97 | .10 | — | 62.00 | .80 | .00 | — | .014 | — |
| | 5 | .47 | .57 | .77 | .10 | — | 17.93 | .80 | .00 | — | .016 | — |

Table 6.—Mean constituent concentrations for the hardwood 1-inch area in 1963

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.33 | 1.36 | 0.26 | 0.20 | 19.94 | 207.13 | 0.33 | 19.65 | 4.73 | 0.134 | 4.393 |
| | 2 | .36 | 1.73 | 1.30 | .20 | 14.84 | 104.80 | .26 | 2.38 | 4.72 | .061 | .593 |
| | 3 | .40 | 1.60 | 1.86 | .16 | 15.82 | 70.66 | .33 | .20 | 4.75 | .042 | .417 |
| Treatment ..... | 1 | .40 | 1.03 | .30 | .30 | 20.54 | 150.60 | .80 | 16.05 | 4.58 | .068 | 4.367 |
| | 2 | .30 | .66 | .86 | .20 | 11.05 | 67.40 | .46 | 2.43 | 4.68 | .035 | .643 |
| | 3 | .40 | .86 | 1.10 | .16 | 11.54 | 72.93 | .53 | .83 | 4.65 | .026 | .247 |

Table 7.—Mean constituent concentrations for the red pine 1-inch area in 1963

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.26 | 1.30 | 0.23 | 0.16 | 12.71 | 125.80 | 0.20 | 12.50 | 4.95 | 0.070 | 2.497 |
| | 2 | .40 | 2.00 | .73 | .13 | 12.93 | 36.46 | .46 | 1.18 | 4.76 | .017 | .377 |
| | 3 | .36 | .96 | 1.16 | .10 | 14.07 | 49.20 | .33 | .58 | 4.57 | .014 | .177 |
| | 4 | .36 | .90 | 1.36 | .16 | — | 36.13 | .46 | — | — | .014 | — |
| | 5 | .50 | .80 | 1.36 | .13 | — | 41.60 | .33 | — | — | .008 | — |
| Treatment ..... | 1 | .46 | 1.26 | .50 | .30 | 17.32 | 121.60 | .46 | 17.80 | 5.04 | .088 | 3.123 |
| | 2 | .30 | 1.90 | .63 | 1.10 | 16.54 | 47.73 | .26 | 1.15 | 4.70 | .021 | .280 |
| | 3 | .36 | 1.36 | .76 | .13 | 15.09 | 48.13 | .53 | .90 | 4.79 | .014 | .170 |
| | 4 | .50 | 1.06 | .90 | .13 | — | 55.53 | .40 | — | — | .014 | — |
| | 5 | .56 | .73 | .76 | .16 | — | 45.50 | .60 | — | — | .010 | — |

Table 8.—Mean constituent concentrations for the old-field 2-inch area in 1967

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.03 | 1.20 | 0.20 | 0.20 | 16.37 | 53.60 | 0.13 | 13.55 | 4.81 | — | 1.793 |
| | 2 | .30 | 1.53 | 1.00 | .20 | 17.10 | 37.86 | .33 | 1.25 | 4.64 | — | .663 |
| | 3 | .03 | .96 | 1.66 | .20 | 14.86 | 53.26 | .00 | .90 | 4.62 | — | .467 |
| | 4 | .13 | .93 | 2.16 | .20 | — | 78.00 | .20 | 1.36 | — | — | — |
| | 5 | .06 | .83 | 1.76 | .20 | — | 39.06 | .13 | 1.25 | — | — | — |
| Treatment ..... | 1 | .26 | 3.36 | 1.36 | .33 | 19.61 | 61.40 | .20 | 42.05 | 5.20 | — | 2.783 |
| | 2 | .13 | 2.23 | 1.10 | .33 | 19.75 | 55.40 | .13 | 2.11 | 4.79 | — | .973 |
| | 3 | .10 | 1.76 | 1.23 | .33 | 18.77 | 55.53 | .13 | 1.58 | 4.68 | — | .420 |
| | 4 | .00 | .96 | 1.00 | .26 | — | 35.33 | .06 | 2.15 | — | — | — |
| | 5 | .03 | .83 | 1.03 | .26 | — | 48.80 | .06 | 1.70 | — | — | — |

Table 9.—Mean constituent concentrations for the hardwood 1-inch area in 1967

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.33 | 1.76 | 0.43 | 0.20 | 24.71 | 138.40 | 0.53 | 28.30 | 4.70 | — | 4.330 |
| | 2 | .40 | 1.30 | 1.26 | .20 | 18.63 | 79.46 | .40 | 2.30 | 4.61 | — | .903 |
| | 3 | .40 | 1.60 | 1.83 | .23 | 21.89 | 94.46 | .33 | 2.70 | 4.59 | — | .713 |
| | 4 | .43 | 1.26 | 1.70 | .16 | — | 65.40 | .40 | 2.60 | — | — | — |
| | 5 | .13 | 1.30 | 1.63 | .16 | — | 87.73 | .13 | 2.88 | — | — | — |
| Treatment ..... | 1 | .16 | 1.80 | .66 | .23 | 15.22 | 117.73 | .33 | 25.15 | 4.83 | — | 3.650 |
| | 2 | .20 | 1.13 | .96 | .30 | 15.79 | 77.26 | .13 | 2.60 | 4.76 | — | .623 |
| | 3 | .30 | .70 | 1.30 | .33 | 12.96 | 86.20 | .33 | 2.16 | 4.82 | — | .570 |
| | 4 | .33 | .63 | 1.90 | .33 | — | 89.66 | .33 | 2.36 | — | — | — |
| | 5 | .33 | .60 | 1.76 | .33 | — | 72.46 | .40 | 3.20 | — | — | — |

Table 10.—Mean constituent concentrations for the red pine 1-inch area in 1967

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.26 | 1.46 | 0.26 | 0.20 | 14.90 | 97.06 | 0.40 | 15.65 | 4.60 | — | 2.133 |
| | 2 | .13 | 1.43 | .53 | .16 | 14.37 | 50.26 | .20 | 1.36 | 4.64 | — | .497 |
| | 3 | .36 | .53 | 1.03 | .16 | 17.48 | 63.93 | .40 | 1.00 | 4.62 | — | .250 |
| | 4 | .26 | .40 | .70 | .20 | — | 62.60 | .26 | 1.90 | — | — | — |
| | 5 | .16 | .33 | .56 | .13 | — | 73.66 | .13 | 2.68 | — | — | — |
| Treatment ..... | 1 | .36 | 1.96 | .66 | .30 | 17.83 | 102.33 | .66 | 35.60 | 5.06 | — | 3.178 |
| | 2 | .33 | 1.30 | .70 | .43 | 12.83 | 68.26 | .33 | 1.42 | 4.92 | — | .340 |
| | 3 | .26 | 1.03 | 1.10 | .30 | 15.73 | 89.86 | .40 | 1.05 | 4.77 | — | .320 |
| | 4 | .66 | 1.03 | 1.50 | .30 | — | 107.20 | .66 | 1.50 | — | — | — |
| | 5 | .50 | 1.80 | 2.20 | .23 | — | 59.40 | .26 | 2.30 | — | — | — |

Table 11.—Mean constituent concentrations for the new gamelands hardwood 2-inch area in 1967

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.16 | 0.90 | 0.10 | 0.16 | 13.43 | 55.93 | 0.26 | 16.50 | 4.55 | — | 2.210 |
| | 2 | .16 | .70 | .33 | .16 | 12.07 | 16.46 | .13 | 2.13 | 4.67 | — | .547 |
| | 3 | .16 | .46 | .33 | .20 | 10.38 | 10.46 | .13 | 1.23 | 4.76 | — | .223 |
| | 4 | .26 | .43 | .53 | .20 | — | 4.80 | .33 | .83 | — | — | — |
| | 5 | .06 | .36 | .56 | .20 | — | 10.13 | .06 | .88 | — | — | — |
| Treatment ..... | 1 | .13 | 1.36 | .40 | .23 | 12.94 | 19.93 | .26 | 75.55 | 5.50 | — | 1.240 |
| | 2 | .06 | .50 | .30 | .23 | 10.76 | 11.86 | .00 | 4.90 | 4.99 | — | .560 |
| | 3 | .13 | .46 | .36 | .23 | 13.37 | 19.20 | .13 | 2.18 | 4.94 | — | .350 |
| | 4 | .16 | .60 | .36 | .20 | — | 16.26 | .13 | 1.92 | — | — | — |
| | 5 | .26 | 1.46 | 1.10 | .26 | — | 15.33 | .20 | 1.50 | — | — | — |

Table 12.—Mean constituent concentrations for the old-field 2-inch area in 1971

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.10 | 2.00 | 0.23 | 0.23 | 14.91 | 15.86 | 0.06 | 10.95 | 5.06 | 0.082 | 2.683 |
| | 2 | .03 | 2.16 | .80 | .23 | 11.56 | 12.13 | .06 | .91 | 4.89 | .016 | .313 |
| | 3 | .00 | 1.80 | 1.43 | .23 | 12.05 | 10.60 | .00 | 1.00 | 4.84 | .009 | .167 |
| | 4 | .03 | 1.53 | 1.63 | .20 | — | 9.46 | .06 | .90 | — | .005 | — |
| | 5 | .00 | 1.16 | 1.50 | .20 | — | 8.66 | .00 | 1.78 | — | .005 | — |
| Treatment ..... | 1 | .43 | 3.33 | 1.73 | .33 | 15.52 | 14.53 | .60 | 50.80 | 5.42 | .095 | 2.300 |
| | 2 | .20 | 2.00 | 1.33 | .30 | 16.36 | 17.20 | .20 | 3.48 | 4.99 | .026 | .343 |
| | 3 | .06 | 1.40 | 1.23 | .33 | 16.68 | 15.80 | .06 | 1.90 | 4.82 | .017 | .190 |
| | 4 | .16 | 1.00 | 1.36 | .30 | — | 15.66 | .06 | 1.66 | — | .020 | — |
| | 5 | .13 | 1.00 | 1.43 | .33 | — | 16.06 | .13 | 1.76 | — | .028 | — |

Table 13.—Mean constituent concentrations for the hardwood 1-inch area in 1971

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.13 | 0.96 | 0.23 | 0.16 | 25.29 | 52.93 | 0.13 | 15.25 | 4.60 | 0.116 | 3.643 |
| | 2 | .26 | 1.23 | 1.23 | .20 | 18.13 | 32.73 | .26 | .98 | 4.83 | .040 | .877 |
| | 3 | .23 | 1.10 | 1.73 | .20 | 12.59 | 23.53 | .13 | .45 | 4.88 | .015 | .267 |
| | 4 | .16 | 1.00 | 2.06 | .20 | — | 14.86 | .06 | .76 | — | .013 | — |
| | 5 | .33 | .80 | 1.70 | .20 | — | 13.13 | .33 | .70 | — | .005 | — |
| Treatment ..... | 1 | .23 | 1.86 | 1.06 | .30 | 16.17 | 26.93 | .26 | 31.60 | 5.01 | .089 | 3.140 |
| | 2 | .30 | 1.13 | 1.46 | .33 | 14.69 | 18.86 | .26 | .50 | 4.85 | .034 | .483 |
| | 3 | .33 | 1.00 | 1.36 | .36 | 12.85 | 17.40 | .33 | .20 | 4.88 | .016 | .230 |
| | 4 | .36 | 1.40 | 1.20 | .36 | — | 16.33 | .26 | .60 | — | .020 | — |
| | 5 | .36 | 1.10 | 1.26 | .36 | — | 21.40 | .26 | 1.56 | — | .018 | — |

Table 14.—Mean constituent concentrations for the red pine 1-inch area in 1971

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.06 | 1.76 | 0.40 | 0.20 | 15.90 | 34.40 | 0.06 | 7.00 | 4.96 | 0.101 | 2.077 |
| | 2 | .30 | 1.93 | 1.20 | .20 | 11.10 | 12.86 | .26 | .66 | 5.04 | .029 | .263 |
| | 3 | .13 | 1.33 | 1.46 | .30 | 11.82 | 12.00 | .06 | .61 | 4.90 | .021 | .137 |
| | 4 | .46 | 1.56 | 1.50 | .23 | — | 10.53 | .26 | .66 | — | .018 | — |
| | 5 | .43 | 1.43 | 1.53 | .33 | — | 9.60 | .06 | 1.05 | — | .017 | — |
| Treatment ..... | 1 | .33 | 3.10 | 1.26 | .30 | 16.79 | 22.93 | .60 | 36.20 | 5.42 | .104 | 2.653 |
| | 2 | .13 | 1.66 | .70 | .33 | 10.32 | 18.40 | .20 | 1.05 | 4.93 | .020 | .437 |
| | 3 | .30 | .66 | .73 | .50 | 13.03 | 19.86 | .20 | .50 | 4.85 | .010 | .160 |
| | 4 | .36 | .46 | .63 | .43 | — | 16.33 | .26 | .65 | — | .013 | — |
| | 5 | .40 | .40 | .53 | .36 | — | 17.40 | .33 | .93 | — | .010 | — |

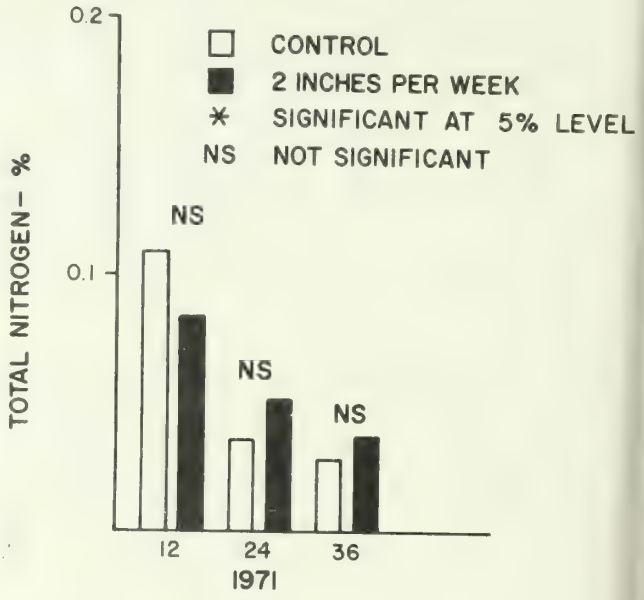
Table 15.—Mean constituent concentrations for the new gameland hardwood 2-inch area in 1971

| Area | Depth, feet | ME/100gms | | | | | PPM | | | pH | %N | %OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Ca | Mg | Na | H | Mn | B | P | | | |
| Control ..... | 1 | 0.00 | 0.53 | 0.10 | 0.20 | 13.72 | 32.73 | 0.06 | 6.25 | 4.96 | 0.109 | 2.867 |
| | 2 | .16 | 1.13 | .80 | .20 | 13.36 | 11.00 | .20 | 3.16 | 4.97 | .036 | .300 |
| | 3 | .26 | .76 | 1.03 | .20 | 11.54 | 10.86 | .26 | .66 | 4.99 | .028 | .230 |
| | 4 | .20 | .53 | .83 | .20 | — | 9.86 | .20 | 1.06 | — | .023 | — |
| | 5 | .00 | .50 | .96 | .16 | — | 7.26 | .00 | .68 | — | .016 | — |
| Treatment ..... | 1 | .06 | 1.86 | .53 | .23 | 7.35 | 4.13 | .13 | 143.75 | 6.15 | .084 | 1.483 |
| | 2 | .03 | .96 | .36 | .20 | 5.20 | 4.93 | .20 | 31.60 | 5.51 | .052 | .413 |
| | 3 | .10 | 1.30 | .73 | .20 | 9.34 | 5.73 | .13 | 9.95 | 5.06 | .037 | .243 |
| | 4 | .03 | 1.10 | .83 | .23 | — | 6.40 | .06 | 1.98 | — | .032 | — |
| | 5 | .13 | .73 | .80 | .23 | — | 4.20 | .20 | .98 | — | .032 | — |

The effects of effluent irrigation on exchangeable potassium, boron, organic matter, pH, and total nitrogen were small and inconsistent. Exchangeable hydrogen concentrations were inconsistently affected by wastewater treatment except in the upper foot of the sandy Morrison soil on the gameland hardwood 2-inch plot. At this location and depth the exchangeable hydrogen in 1971 was 13.7 m.e./100g in the control area and only 7.3 m.e./100g in the treatment area.

Although total nitrogen had no significant change in concentration as a result of treatment, it is an important constituent associated with wastewater disposal. For this reason, the average concentrations of total nitrogen at various depths in the treated and control old-field 2-inch plot for 1963, 1967, and 1971 and gameland hardwood 2-inch plot for 1967 and 1971 are indicated in figures 2 and 3.

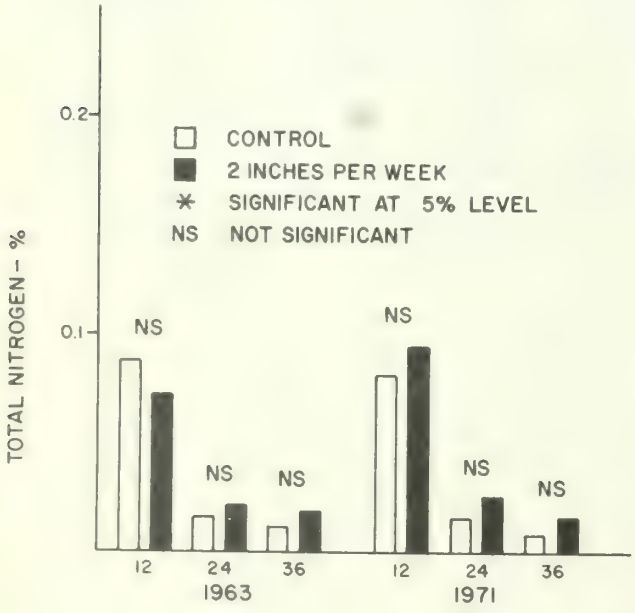
Figure 3.—Average concentration of percent total nitrogen at various depths in the treated and control gameland hardwood 2-inch plots (Morrison sandy loam).




### Element Concentrations Affected by Effluent Irrigation

The element concentrations that were more frequently affected significantly by effluent irrigation were calcium, magnesium, sodium, manganese, and phosphorus.

Figure 2.—Average concentration of percent total nitrogen at various depths in the treated and control old-field 2-inch plots (Hublersburg silt loam).




Calcium and magnesium concentrations increased significantly at the 1-foot depth. For example, the concentrations of calcium and magnesium in the Hublersburg silt loam on the old-field 2-inch plot in 1971 were 2.0 and 3.3 m.e./100g for the calcium control and treatment, respectively, and 0.2 and 1.7 m.e./100g for the magnesium control and treatment, respectively.

These increases may be due to the strong adsorptive power that soil colloids have for calcium and magnesium. Calcium and hydrogen have approximately the same bonding strength with respect to soil colloids. If calcium is applied to the soil, the cation-exchange reaction is reversed, and hydrogen and weaker bonded cations are replaced by a mass action of active calcium ions. As a result, the soil becomes higher in exchangeable calcium and lower in hydrogen. As the soil adjusts to this altered proportion of bases and hydrogen, the soil pH is raised and the chemical makeup is modified.

The average concentrations of calcium and

magnesium at various depths in the treated and control old-field 2-inch plot for 1963, 1967, and 1971 and the new gameland hardwood 2-inch plot for 1967 and 1971 are indicated in figures 4 through 7.

The concentration of exchangeable sodium increased in all the depths as a result of treatment. The increase in concentration was experienced in all the vegetative types, and an increase was seen throughout the 9 years of treatment. The samples taken in 1971 from the treated plots showed a range in maximum exchangeable sodium from 0.5 m.e./100g in the red pine 1-inch area on the fine-textured Hublersburg soil to 0.2 m.e. /100g in the new gameland hardwood 2-inch area on the sandy Morrison soil. These values are equivalent, respectively, to exchangeable sodium percentage values of 2.9 and 3.2.

In a review of the literature by Edwards *(1968)* it was indicated that much of the concern about soil chemical changes focused on changes in sodium concentrations relative to the other exchangeable cations in the soil. This concern with exchangeable sodium stems from the well-documented research in irrigation agriculture, which has shown that, when the exchangeable sodium percentage reaches a value of about 15, a deterioration of soil structure and adverse effects on infiltration can be expected in medium- and fine-textured soils. Thus it appears highly probable that, with the present effluent quality and applicatoion rates, sodium will not present a hazard to soil structure and permeability.

The average concentrations of sodium at various depths resulting from applications of 1 and 2 inches of effluent per week in the hardwood 1-inch and old-field 2-inch plots, respectively, are indicated in figure 8.

The average concentrations of sodium at various depths in the treated and control old-field 2-inch plot for 1963, 1967, and 1971 and the gameland hardwood 2-inch plot for 1967 and 1971 are indicated in figures 9 and 10.

Manganese, although not commonly measured among exchangeable cations, was included because of the possible effect of the increased wetness on the solubilization of manganese by oxidation-reduction reactions.

The average concentration of manganese decreased significantly in the upper 3 feet of the hardwood 1-inch plot on the fine-textured Hublersburg soil and the upper 3 feet of the gameland hardwood 2-inch plot on the sandy Morrison soil. The other areas and depths had small and inconsistent changes. This reduction in the manganese concentration could be due to the slightly more acidic conditions in the hardwood 1-inch treated plot and the extra effluent added year round in the gameland hardwood 2-inch treated plot. Manganese tends to dissolve and wash out in soils with conditions such as low pH and increased wetness.

The average concentrations of manganese at various depths in the treated and control old-field 2-inch plot for 1963, 1967, and 1971 and the gameland hardwood 2-inch plot for 1967 and 1971 are indicated in figures 11 and 12.

Boron concentrations increased significantly at the 1-foot depth in the Hublersburg soil on the old-field 2-inch, hardwood 1-inch, and red pine 1-inch plots and in the 1-foot depth of the Morrison soil on the gameland hardwood 2-inch plot. Boron concentrations should not be expected to change much as a result of irrigation. Soil has a poor ability to build up boron due partly to the relatively weak bonding between boron ions and soil colloids. Also, boron concentrations in the effluent were relatively low compared to cation concentrations present.

The average concentrations of boron at various depths in the treated and control old-field 2-inch plot for 1963, 1967, and 1971 and the gameland hardwood 2-inch plot for 1967 and 1971 are indicated in figures 13 and 14.

When phosphorus is added to soils it usually is in the soluble orthophosphate form. The orthophosphate anions bond chemically with surfaces of iron and aluminum oxyhydroxides and will form precipitates with iron and aluminum when these are in solution. The strength of the bonds formed from surface and precipitation reactions varies. The weakest bonded are the most soluble phosphates

which readily equilibrate with the soil solution and become available to plants. A good measure of the amount of available phosphorus is the Bray dilute-acid/ dilute-fluoride extraction.

There was a significant increase in the concentration of Bray-tested phosphorus at the 1-foot depth in the Hublersburg silt loam soil on the old-field 2-inch plot, the hardwood 1-inch plot, and the red pine 1-inch plot. There was no significant change in the concentration of Bray phosphorus below the 1-foot depth. Since the vegetation was not removed from the plots, the phosphorus contained in the vegetation was recycled through and built up in the soil.

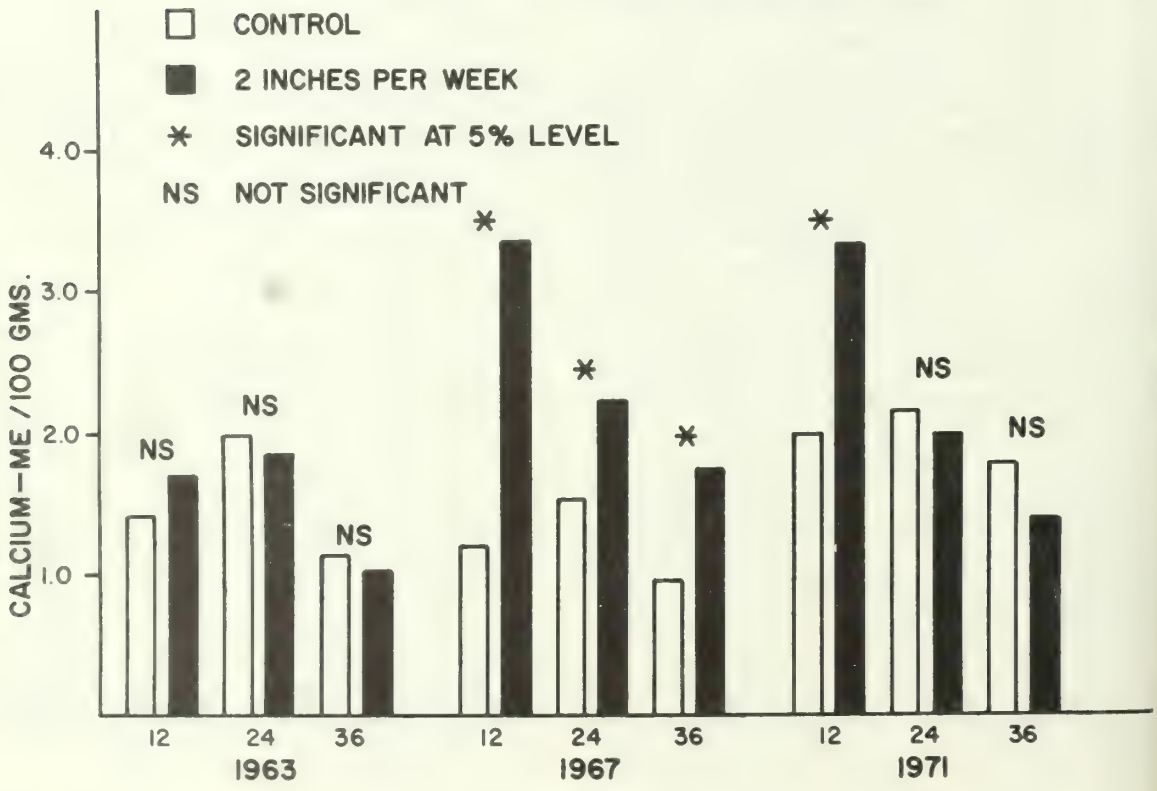
Bray phosphorus concentrations increased significantly to a depth of 5 feet in the Morrison sandy loam soil on the gameland hardwood 2-inch plot. The Morrison sandy loam soil had a very large increase in Bray phosphorus in response to the year-round effluent irrigation. In 1971, after 7 years of treatment, the irrigated plots had 143.8, 31.6, and 9.9 $\mu$g P/gram of soil while the control had 6.3, 3.2, and 0.7$\mu$g P/gram of soil in the respective depths.

The average concentrations of phosphorus at various depths in the treated old-field 2-inch and hardwood 1-inch plots on Hublersburg silt loam for 1963, 1967, and 1971 are indicated in figure 15.

The average concentrations of phosphorus at various depths in the treated and control old-field 2-inch plot for 1963, 1967, and 1971 and the gameland hardwood 2-inch plot for 1967 and 1971 are indicated in figures 16 and 17.

Text continues on page 19.

Figure 4.—Average concentration of calcium at various depths in the treated and control old-field 2-inch plots (Hublersburg silt loam).



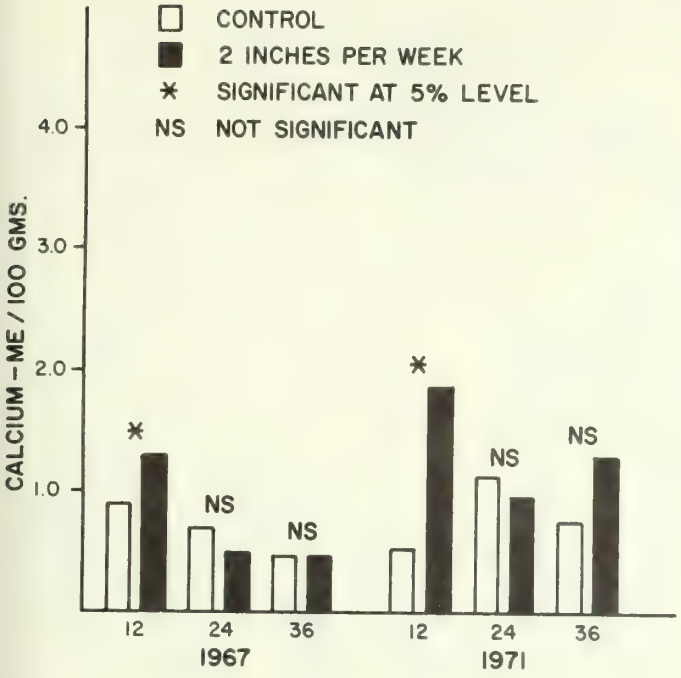



Figure 5.—Average concentration of calcium at various depths in the treated and control gameland hardwood 2-inch plots (Morrison sandy loam).

Figure 6.—Average concentration of magnesium at various depths in the treated and control old-field 2-inch plots (Hublersburg silt loam).

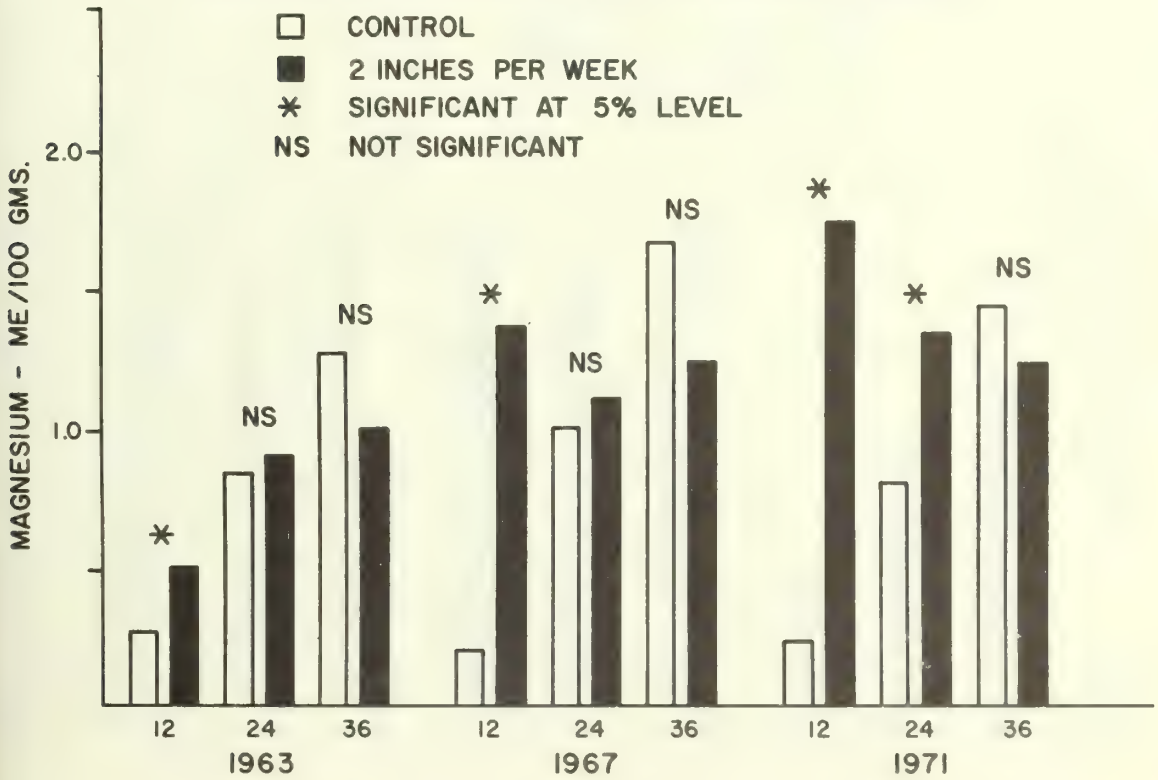


Figure 7.—Average concentration of magnesium at various depths in the treated and control gameland hardwood 2-inch plots (Morrison sandy loam).

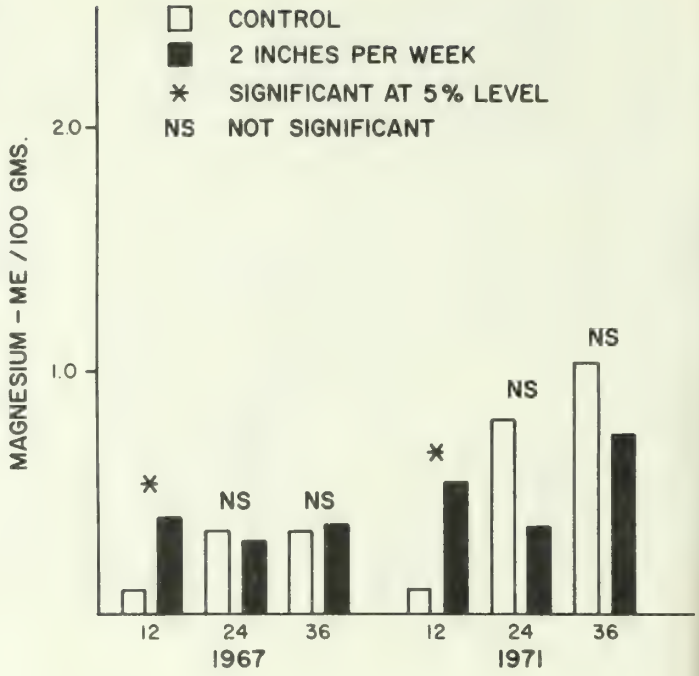



Figure 8.—Average concentration of sodium at various depths in the treated old-field 2-inch and hardwood 1-inch plots (Hublersburg silt loam).

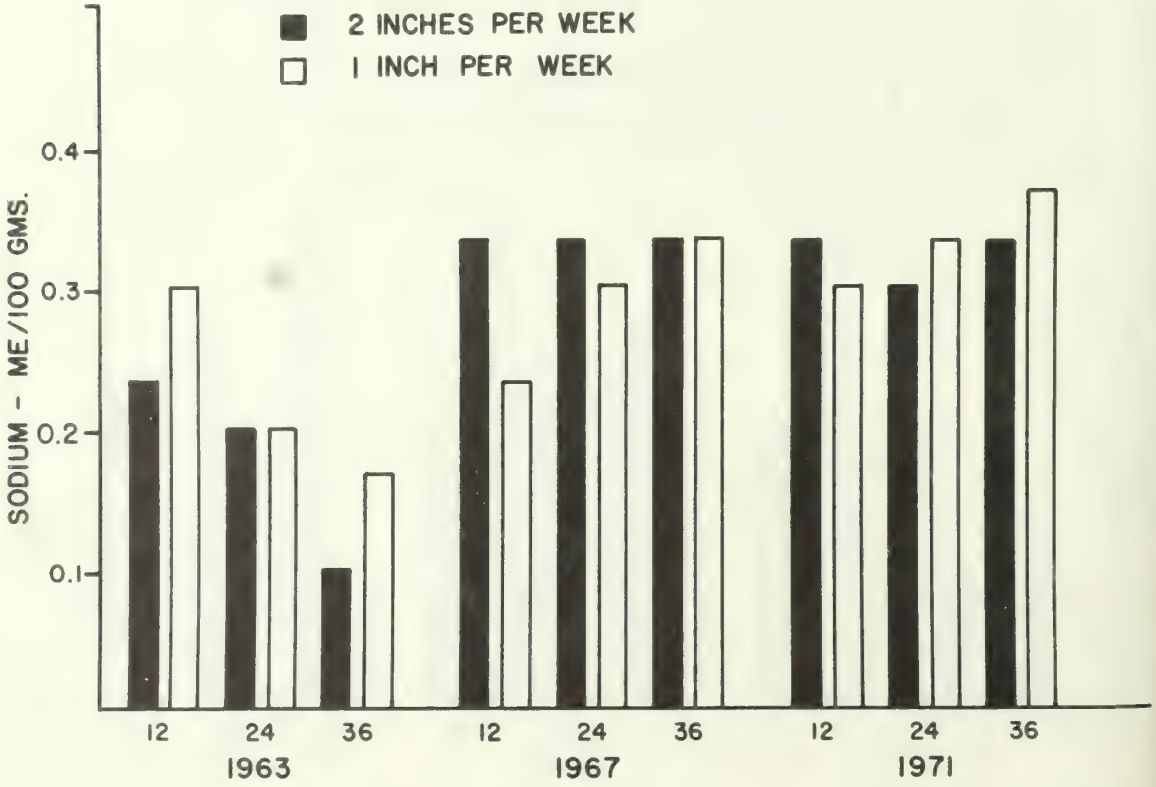
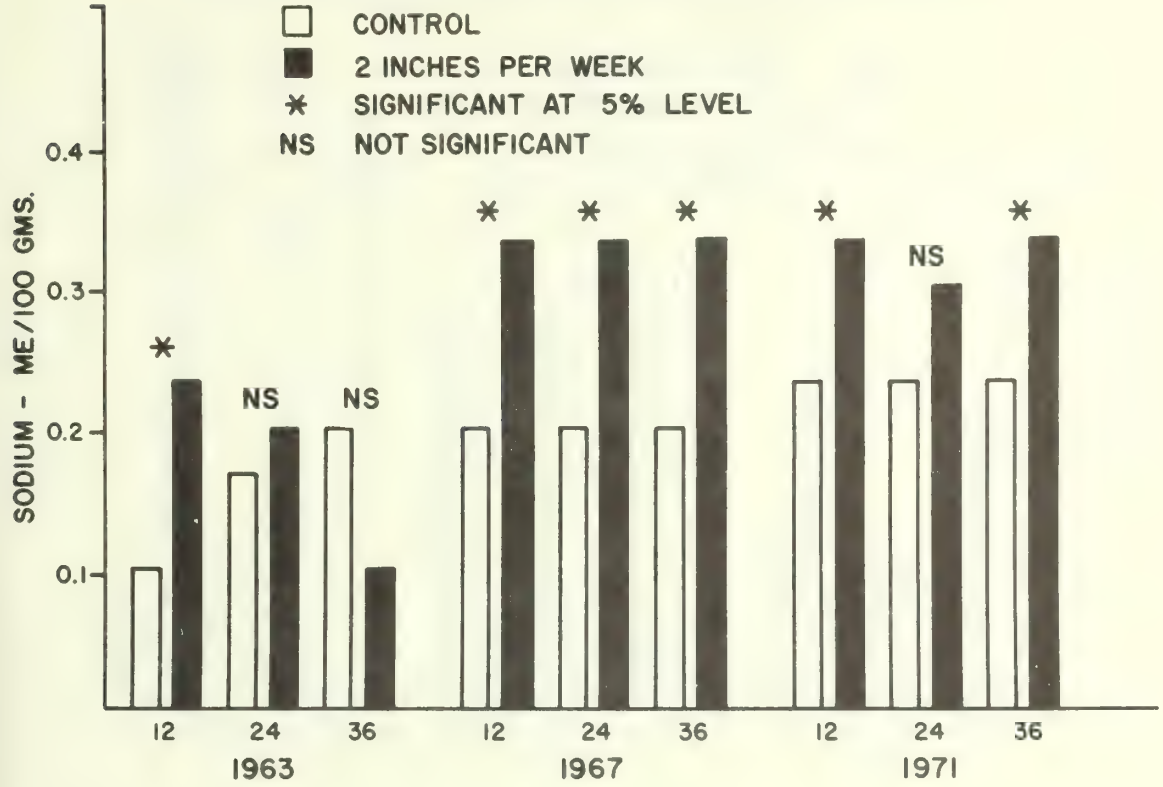


Figure 9.—Average concentration of sodium at various depths in the treated and control old-field 2-inch plots (Hublersburg silt loam).



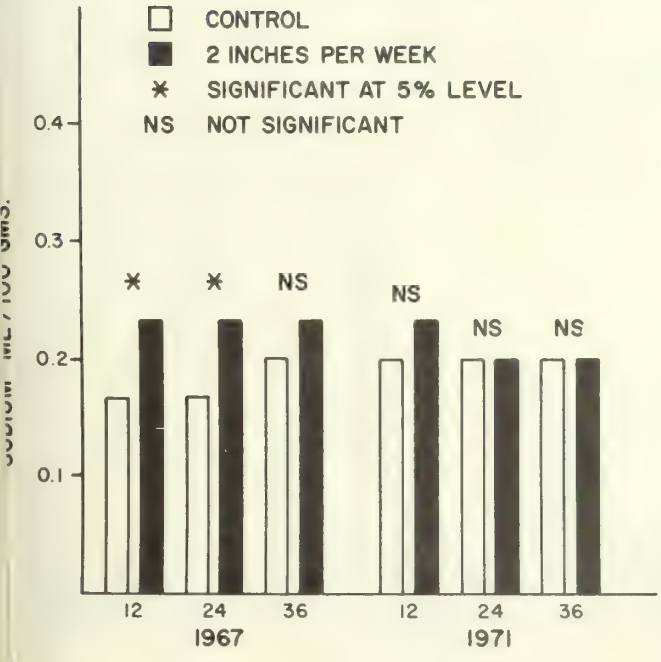
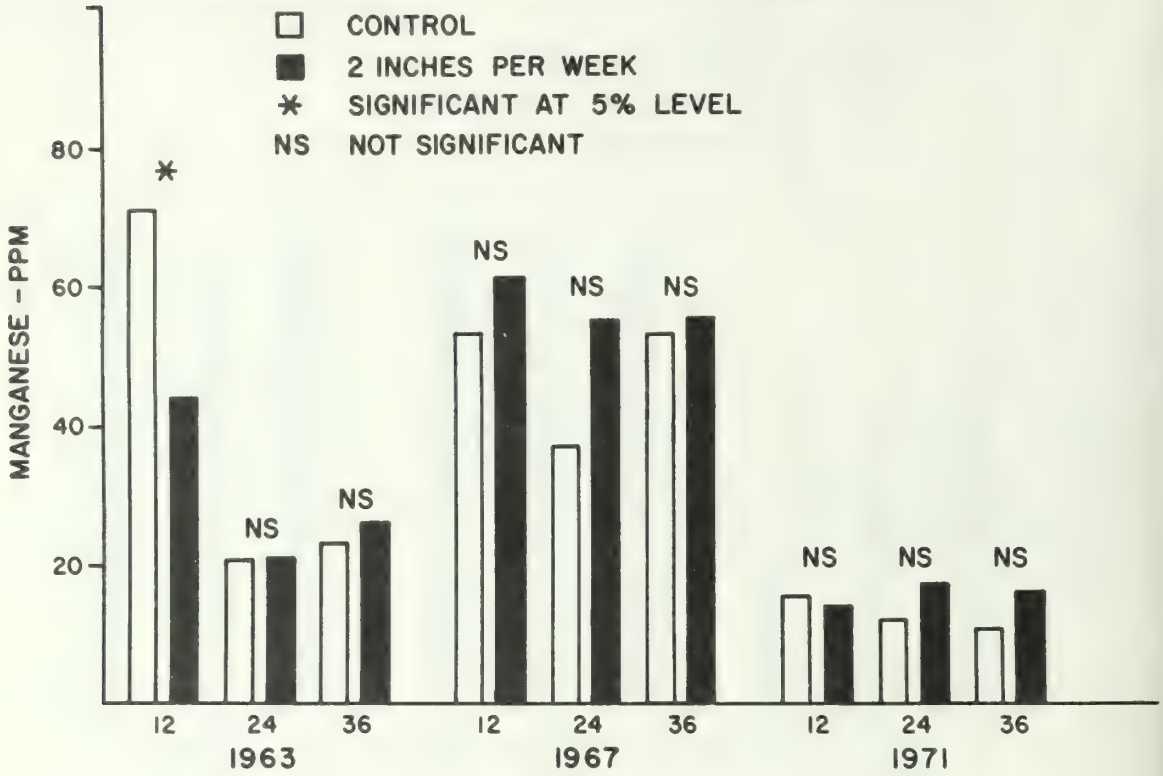




Figure 10.—Average concentration of sodium at various depths in the treated and control gameland hardwood 2-inch plots (Morrison sandy loam).

Figure 11.—Average concentration of manganese at various depths in the treated and control old-field 2-inch plots (Hublersburg silt loam).



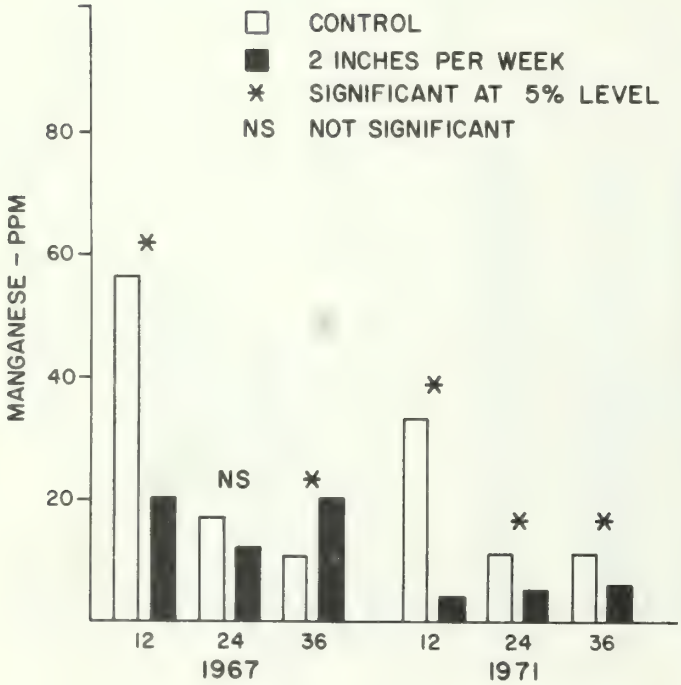




Figure 12.—Average concentration of manganese at various depths in the treated and control gameland hardwood 2-inch plots (Morrison sandy loam).

Figure 13.—Average concentration of boron at various depths in the treated and control old-field 2-inch plots (Hublersburg silt loam).

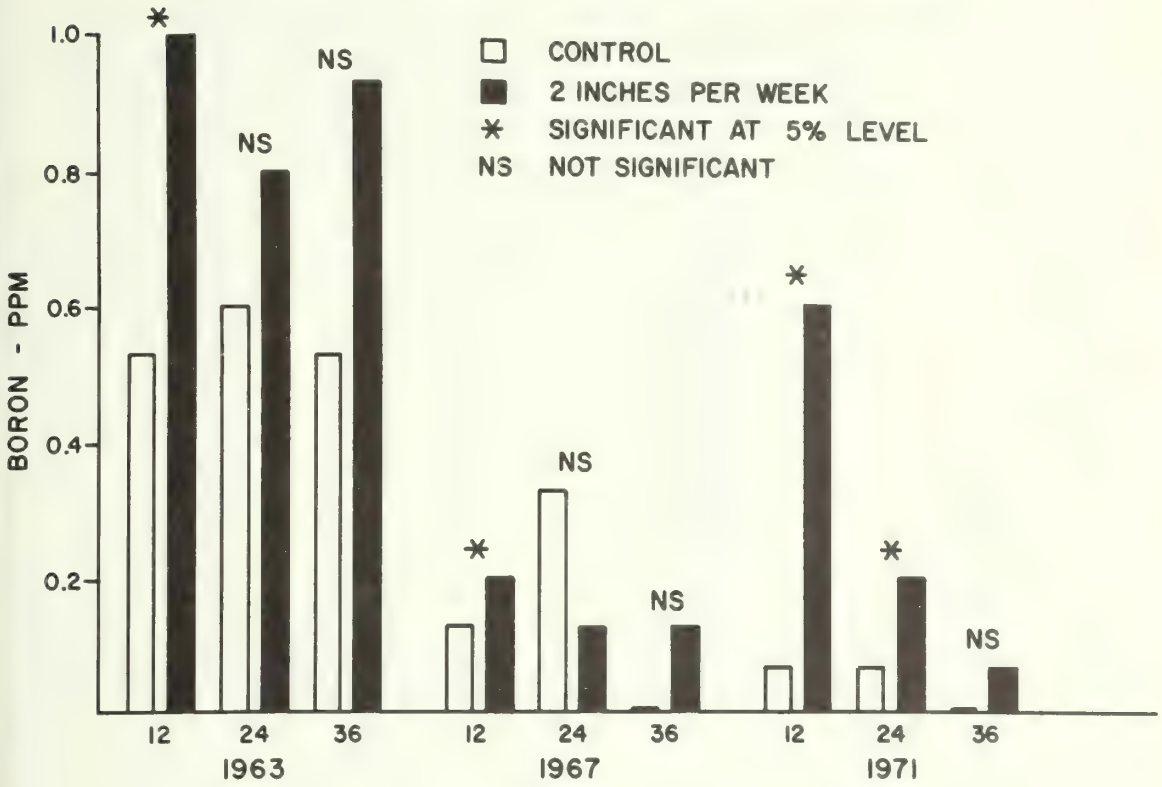



Figure 14.—Average concentration of boron at various depths in the treated and control gameland hardwood 2-inch plots (Morrison sandy loam).

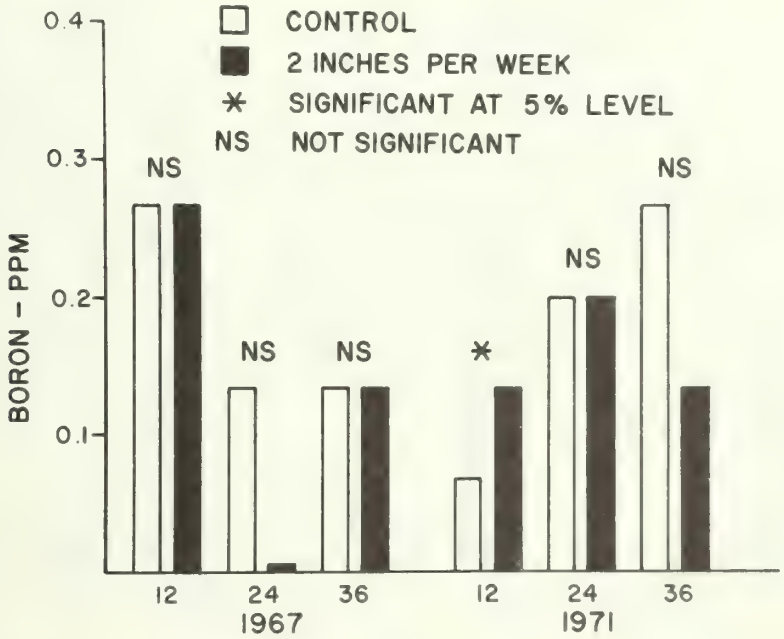


Figure 15.—Average concentration of phosphorus at various depths in the treated old-field 2-inch and hardwood 1-inch plots (Hublersburg silt loam).

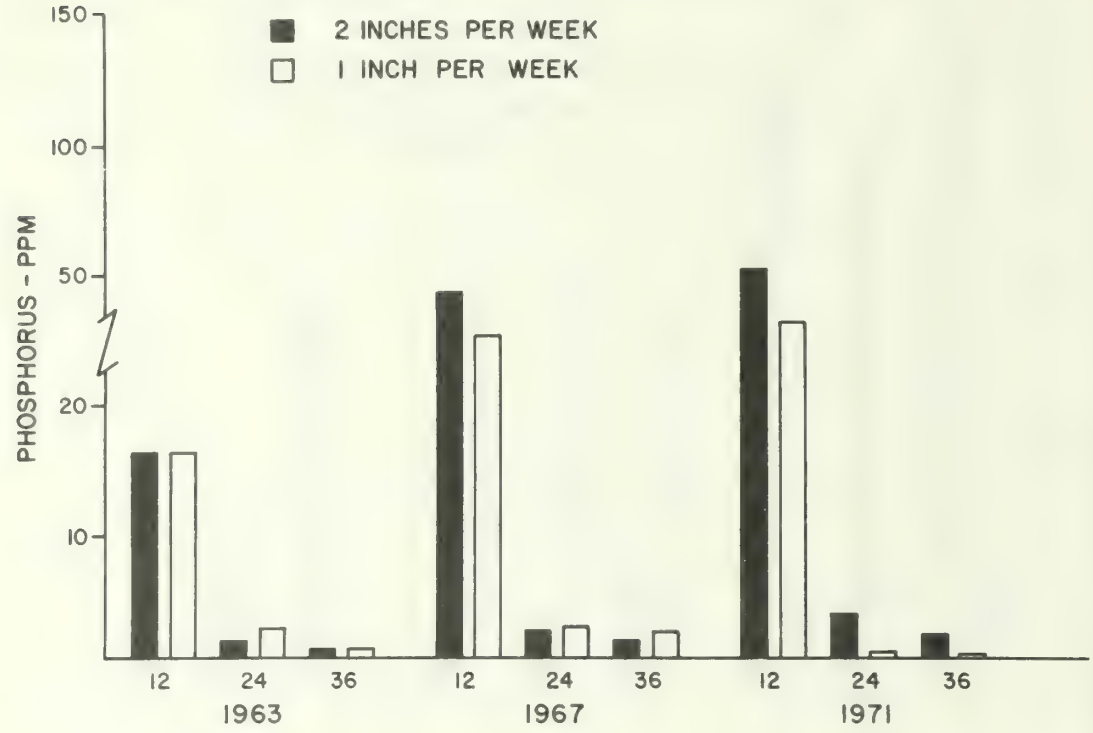



Figure 16.—Average concentration of phosphorus at various depths in the treated and control old-field 2-inch plots (Hublersburg silt loam).

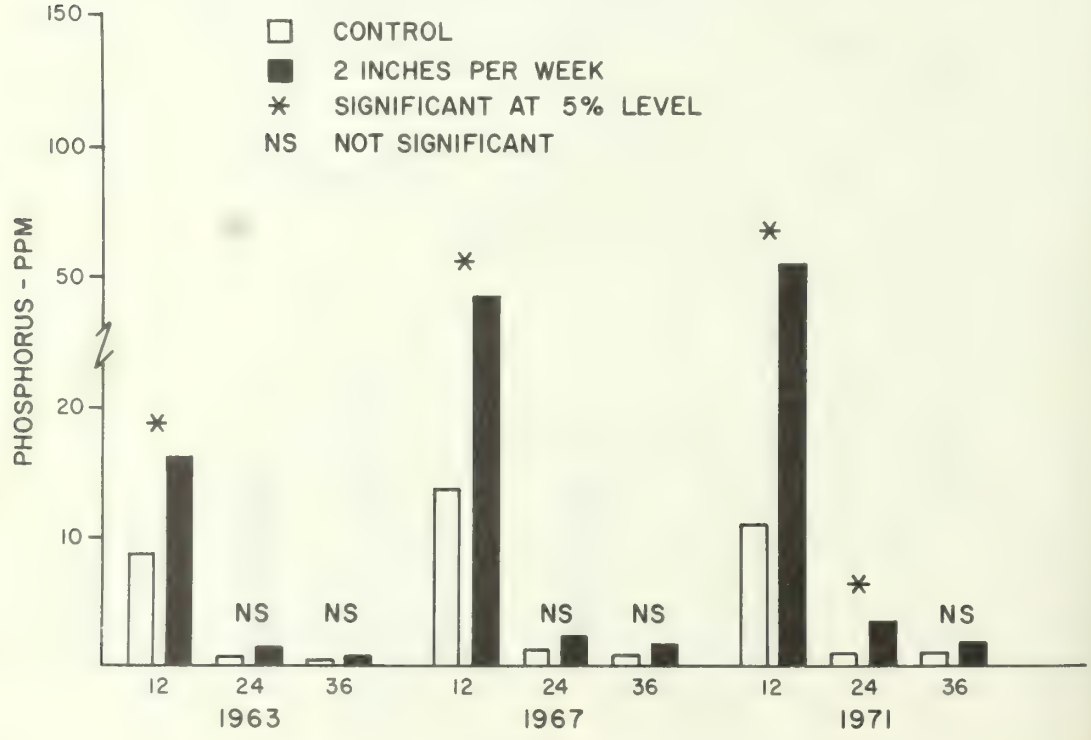
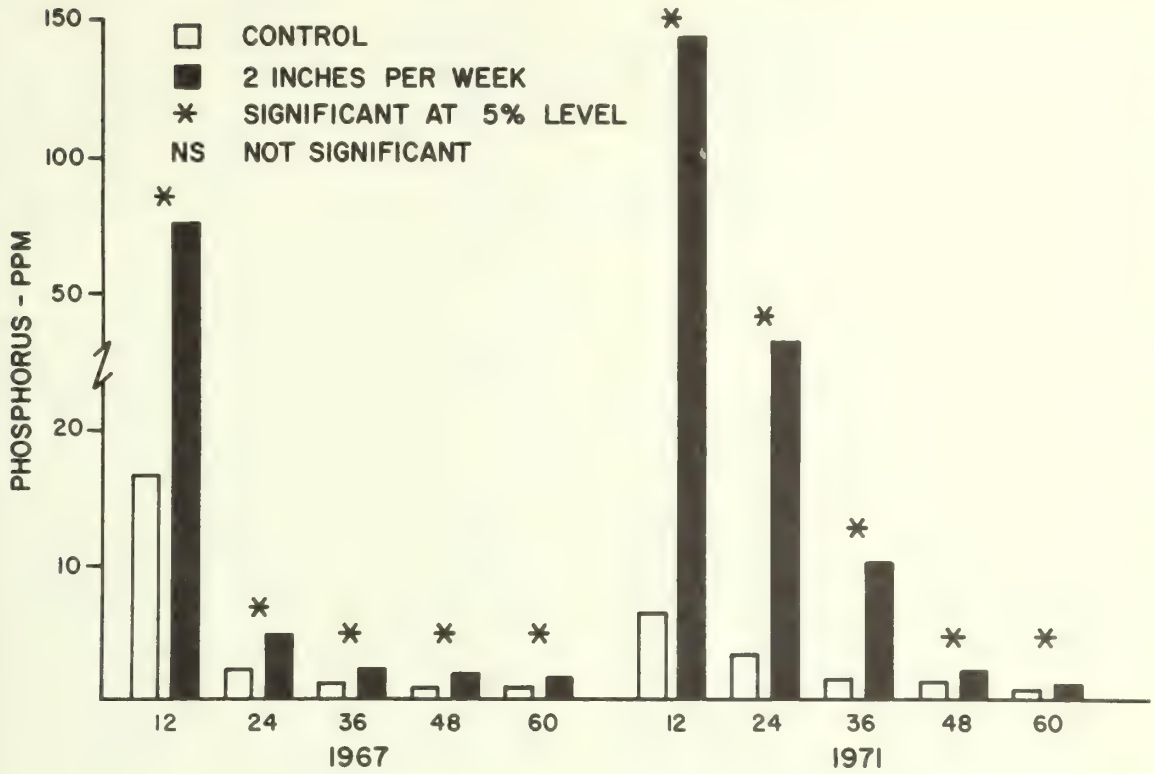


Figure 17.—Average concentration of phosphorus at various depths in the treated and control gameland hardwood 2-inch plots (Morrison sandy loam).




**Effect of Vegetative Cover Type on Element Concentrations**

The effect of vegetative cover tpye on the concentrations of the various elements was determined by comparing the mean constituent concentrations in the hardwood 1-inch treatment plot and the red pine 1-inch treatment plot. Both plots were located on Hublersburg silt loam, and both received applications of effluent at the rate of 1 inch per week. Both received the same seasonal and total amounts of effluent applied over the 9-year study period. The two areas had similar slopes and aspects and were located adjacent to each other.

Of the 11 constituents analyzed, potassium, calcium, magnesium, boron, and organic matter showed significant differences between areas.

Potassium was significantly higher throughout all five depths of the red pine 1-inch treatment plot in 1967. There were no significant differences for the 1963 and 1971 samples.

Calcium concentrations were significantly higher in the second and third foot of the red pine 1-inch treatment plot in 1963. In 1967 the differences were inconsistent. In 1971 the calcium concentrations were significantly higher in the lower 3 feet of the hardwood 1-inch treatment plot.

Magnesium concentrations were not significantly different in 1963 and 1967, but were significantly higher in the lower 4 feet of the hardwood 1-inch treatment plot in 1971.

Boron concentrations were significantly higher in the upper 2 feet of the hardwood 1-inch treatment plots in 1963. In 1967 boron differences were inconsistent except in the upper 2 feet, where the red pine 1-inch treatment plot had significantly higher concentrations. In 1971, the red pine 1-inch treat-

Table 16.—Average chemical content of the tree foliage in the hardwood 1-inch and red pine 1-inch plots at the end of the 1971 irrigation season

| Plot | N | P | K | Ca | Mg | Mn | Fe | Cu | B | Al | Zn | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Percent of dry weight* | | | | | μg/g | | | | | | |
| Hardwood 1-inch: | | | | | | | | | | | | |
| Irrigated | 2.64 | 0.19 | 1.17 | 1.12 | 0.12 | 1,191 | 132 | 11 | 57 | 79 | 38 | 18 |
| Control | 2.99 | .20 | .90 | .98 | .19 | 1,623 | 133 | 10 | 86 | 61 | 38 | 17 |
| Red pine 1-inch: | | | | | | | | | | | | |
| Irrigated | 1.40 | .14 | .40 | .23 | .06 | 1,273 | 55 | 4 | 15 | 206 | 37 | 3 |
| Control | 2.11 | .13 | .51 | .23 | .08 | 790 | 52 | 4 | 22 | 92 | 24 | 2 |

ment plot had a significantly higher boron concentration in the first foot.

Organic matter was significantly higher in the second- and third-foot depths of the hardwood 1-inch treatment plot in 1963 and 1967, but was not significant in 1971.

The differences between the concentrations of calcium, magnesium, and boron in the Hublersburg soil on the hardwood 1-inch and red pine 1-inch treated plots are possibly due to the effects of the foliage. Foliage in hardwood stands contains higher concentrations of calcium, magnesium, and boron than the foliage in red pine stands (table 16). When this foliage drops to the ground and decomposes, the nutrient concentrations are recycled in the soil, causing an increase in the soil's nutrient concentrations.

The decrease in the potassium concentrations could be caused by the replacement of the weaker bonded potassium ions by the stronger bonded calcium and magnesium ions supplied by the decomposing litter.

The difference in the percentage of organic matter between the two vegetative types was present at the beginning of the study and therefore could be due to the characteristics of the study site rather than differences due to different vegetative cover effects.

### Change in Element Concentrations

Of the 11 constituents analyzed, only exchangeable potassium, sodium, manganese, and hydrogen and extractable boron and phosphorus had significant changes in time.

The potassium concentrations decreased significantly from 1963 to 1967 in all five depths of the Hublersburg soil in the old-field 2-inch treated plots. This change was accompanied by a significant decrease in the potassium concentrations in all five depths in the control plots of the old-field 2-inch area. Since the change occurred in both the treated and control areas, unknown factors other than effluent treatment must have been responsible.

Sodium concentrations increased significantly from 1963 to 1967 in the five depths of the Hublersburg soil on the old-field 2-inch treated plot, the second- and third-foot depths of the hardwood 1-inch treated plot, and the lower 3 feet of the red pine 1-inch treated plot. As the sodium was applied to the soil by the effluent irrigation, the concentrations increased until an equilibrium exchangeable sodium level was reached. This point was reached by the time the 1967 samples were taken, since there was no change in exchangeable sodium levels from 1967 to 1971.

Manganese concentrations decreased significantly from 1967 to 1971 in all five depths of the Hublersburg soil on the old-field 2-inch, hardwood 1-inch, and red pine 1-inch treated plots, and in all five depths of the Morrison soil on the gameland hardwood 2-inch treated plots. These changes in concentrations in the treated plots were accompanied by significant decreases in manganese from 1967 to 1971 in all five depths of the control plots. Since there was a high concentration of manganese present in the soil before treatment began, it is possible that the changes in the control and treated areas were caused by differences in sampling positions and the greater leaching that occurred in the wetter meterological years from 1967 to 1971.

The exchangeable hydrogen concentrations decreased significantly from 1967 to 1971 in the upper 3 feet of the Morrison soil on the gameland hardwood 2-inch treated plot. This change could be due to the increased adsorption of calcium and magnesium from the effluent applied throughout the year at a level of 2 inches per week.

The changes in boron concentrations were small and inconsistent in the treated areas. In the control areas, however, the boron concentrations decreased significantly in all five depths of the Hublersburg soil on the old-field 2-inch and red pine 1-inch plots from 1963 to 1971. These changes in the boron concentrations could be reflections of the higher annual precipitation and leaching in the study area since 1967.

Phosphorus concentrations increased significantly from 1963 to 1971 in the upper foot of the Hublersburg soil on the hardwood 1-inch and red pine 1-inch treated areas, and in the upper 3 feet of the Hublersburg and Morrison soils on the old-field 2-inch and gameland hardwood 2-inch plots respectively. These buildups in the phosphorus concentrations over time reflect the soil's ability to fix and hold phosphorus in an unavailable form. Changes in phosphorus concentrations were small and inconsistent in the control areas.

## SUMMARY AND CONCLUSIONS

From the results reported here, we made the following conclusions about what effects sewage effluent irrigation had on the chemical properties of Hublersburg silt loam and Morrison sandy loam:

1. The plots irrigated with sewage effluent had significant increases in the concentrations of calcium, magnesium, sodium, boron, and phosphorus, and significant decreases in manganese concentrations.

   Calcium and magnesium concentrations increased significantly at the 1-foot depth in all plots. Changes below the 1-foot depth were small and inconsistent.

   Sodium concentrations increased significantly at all depths in all plots.

   Boron concentrations increased significantly in the upper foot of all plots.

   Phosphorus concentrations increased significantly in the Hublersburg soil in the 1-foot depth of the hardwood 1-inch plot, the upper 2 feet of the old-field 2-inch and red pine 1-inch plots; and at all depths of the Morrison soil on the gameland hardwood 2-inch plot.

   Manganese concentrations decreased significantly in the upper 3 feet of the Hublersburg soil on the hardwood 1-inch treated plot and the upper 3 feet of the Morrison soil on the gameland hardwood 2-inch treated plot.
2. A comparison of the 11 constituent concentrations in the hardwood 1-inch and red pine 1-inch plots indicated that potassium, calcium, magnesium, boron, and organic matter had significant differences. Of these five, only calcium and magnesium had significant differences after the ninth year of treatment. Both calcium and magnesium concentrations were significantly higher in the lower 3 feet of the soil in the hardwood 1-inch plot.
3. Of the 11 constituents analyzed, only potassium, sodium, manganese, exchangeable hydrogen, boron, and phosphorus had significant changes over time.

   Potassium concentrations decreased from 1963 to 1967 in all five depths of the treated and control plots in the Hublersburg soil on the old-field 2-inch plots.

   Sodium concentrations increased significantly from 1963 to 1967 in all five depths of the Hublersburg soil in the old-field 2-inch treated plot, the second- and third-foot depths of the hardwood 1-inch treated plot, and the lower 3 feet of the red pine 1-inch treated plots.

   Manganese concentrations decreased significantly from 1967 to 1971 in all five depths of the Hublersburg soil on the old-field 2-inch, hardwod 1-inch, and red pine 1-inch treated plots, and in all five depths of the Morrison soil on the gameland hardwood 2-inch treated plot.

   Exchangeable hydrogen concentrations decreased significantly from 1967 to 1971

in the upper 3 feet of the Morrison soil on the gameland hardwood 2-inch treated plot.

Boron decreased significantly in all five depths of the Hublersburg soil on the old-field 2-inch and red pine 1-inch treated plots from 1963 to 1971.

Phosphorus increased significantly from 1963 to 1971 in the upper foot of the Hublersburg soil on the hardwood 1-inch and red pine 1-inch treated plots, and in the upper 3 feet of the Hublersburg soil on the old-field 2-inch and the Morrison soil on the gameland hardwood 2-inch treated plots.

4. It can be concluded that, after 9 years of spray irrigation with treated municipal waste water, there were no indications that the treatment had any detrimental effects on the soil.

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## Table 17.—Description of Hublersburg soil series

[Hublersburg silt-loam, cultivated (B-1, 3-8% slope)]

GENERAL

Hublersburg is a deep, well-drained intergrade of red and yellow and gray-brown podzolic soils developed from limestone and dolomite. It differs from the Hagerstown by being yellower in the B horizon (7.5 yr hue and yellower) and generally having more chert in all the horizons; and it differs from the Morrison by having finer textured B horizons. Hublersburg stands alone in the catena in Centre County except for a shallow phase. The moderately-well to somewhat poorly-drained Lawrence poorly-drained Guthrie and the very-poorly-drained Burgin — the usual associates of Hagerstown and Hublersburg in the drainage catena—are, in Centre County, associated with Araby and Wiltshire as local alluvium soils.

| Profile | | Description |
|---|---|---|
| Horizon | Depth | |
| | *Inches* | |
| Ap ..... | 0-8 ..... | Silt loam; moderate, very fine crumb or granular structure; brown to yellowish brown (10 yr 4/3-5/4 moist); friable when moist, slightly sticky when wet. pH 5.8. Chert fragments numerous. |
| $B_{21}$ ..... | 8-24..... | Silty clay or clay loam; moderately durable, fine to medium subangular blocky structure; brownish yellow or yellowish brown (10 yr 6/6-5/6 moist); very firm when moist, plastic when wet. pH 5.8. |
| $B_{22}$ ..... | 24-48..... | Heavy silty clay or clay; tough, moderately durable, coarse blocky structure; yellowish brown to brownish yellow (10 yr 5/4-6/6 moist) with some dark brown (7.5 yr 4/2-4/4 moist) very firm when moist; plastic when wet. pH 5.6. |
| C ..... | 48+..... | Limestone |

*Range in Characteristics*

Small areas of brown and reddish-brown soils occur. Fragments of chert and limestone are scattered locally over the surface and in profile. Outcroppings of limestone are common.

*Physiography and Relief*

Slightly to steeply rolling upland. Some karst topography.

*Drainage*

Well-drained. Permeability is moderate to moderately rapid.

*Vegetation*

A high percentage is under cultivation. Forested areas contain mixed hardwoods.

## Table 18.—Description of Morrison soil series

[Morrison sandy loam; woods site near cropland (B-1, 3-8% slope)]

GENERAL

Morrison is a deep, well-drained intergrade of the red and yellow and gray-brown podzolic soils developed from sandstone and low-grade limestone and dolomite. It develops from the Gatesburg formation. It is redder and finer textured than the Gatesburg series. It differs from the Hagerstown and Hublersburg by being sandy throughout the profile. Normally it is deeper to bedrock. It is redder throughout the profile than the Hublersburg. Morrison stands alone in the drainage catena.

| Profile | | Description |
|---|---|---|
| Horizon | Depth | |
| | *Inches* | |
| $A_1$ | 0-4 | Sandy loam to fine sandy loam; moderate, very fine granular structure when moist; very dark gray-brown (10 yr 3/2 moist); very friable when moist, non-sticky when wet. pH 5.2. Numerous small chert fragments present, with some larger sandstone pieces. |
| $A_2$ | 4-11 | Sandy clay loam; moderate, very fine granular structure when moist; yellowish-brown (10 yr 5/6-5/8 moist); slightly sticky when wet. Lower boundary coarse-wavy. pH 5.2. Numerous small chert fragments present. |
| $B_2$ | 11-20 | Clay loam; moderate, very fine angular-blocky structure when moist; strong brown (7.5 yr 5/6 moist); firm consistency when moist, very sticky when wet. Coarse-wavy lower boundary. pH 5.4. |
| $B_{22}$ | 20-60+ | Clay loam; moderate, coarse-angular, blocky structure with some platyness when moist; strong brown (7.5 yr 5/8 moist); firm consistency when moist, very sticky to plastic when wet. pH 5.4. Chert fragments and sandstone channers are present. Very few roots in this zone. Manganese dioxide coatings are very numerous, with small bits of iron ore giving this horizon a blackish look. |

*Range in Characteristics*

On cultivated land the range in color as described may not be present because of disturbance. 7.5 yr 5/8 moist to 5 yr 5/8 moist seems to predominate. The $A_2$, as a rule, is incorporated in the Ap, and the other horizons will be clay loam. The textures of the surface will range from fine to coarse sandy loam. The chert content will vary considerably from slightly cherty to very cherty. The platy structure is not always found in the $B_{22}$.

*Physiography and Relief*

Rolling uplands with some karst topography; slopes 1 to 12%. Occasional sinkholes outside karst topography.

*Drainage*

Well-drained. Permeability is moderately rapid to rapid.

*Vegetation*

In wooded areas, the vegetation is mostly white and black oak, ash, maple, white pine, and other species of hardwoods.

**Acknowledgments**

The research reported here is part of the program of the Waste Water Renovation and Conservation Project of the Institute for Research on Land and Water Resources and Hatch Project No. 1809 of the Agricultural Experiment Station, The Pennsylvania State University, University Park, Pennsylvania.

The work upon which this report is based was supported by funds provided by the Northeastern Forest Experiment Station of the USDA Forest Service, through the Pinchot Institute Consortium for Environmental Forestry Research.

Richenderfer, James L., William E. Sopper, and Louis T. Kardos.
1975. **Spray-irrigation of treated municipal sewage effluent and its effect on the chemical properties of forest soils.** NE For. Exp. Stn., Upper Darby, Pa.
24 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-17)

Several forested areas on two soil types at the Waste Water Renovation and Conservation Project at The Pennsylvania State University were irrigated with treated municipal sewage effluent for 9 years (1963-71). Soil samples were collected to a depth of 5 feet in 1963, 1967, and 1971. These samples were analyzed to determine if any significant changes had occurred in the chemical properties of the soils as a result of the effluent irrigation. No detrimental effects were observed.

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**Key Words:** Wastewater, sewage effluent, forest soils, spray irrigation, land disposal

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**Key Words:** Wastewater, sewage effluent, forest soils, spray irrigation, land disposal

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F. BRYAN CLARK, STATION DIRECTOR

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, UPPER DARBY, PA.

# 1974 at the Northeastern Station

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NORTHEASTERN FOREST EXPERIMENT STATION
F. BRYAN CLARK, STATION DIRECTOR ● 1975

# 1974: GENERAL

1974 WAS A YEAR of many changes at the Northeastern Forest Experiment Station.

F. Bryan Clark is the new Station Director. Clark came to the Station in June from the North Central Station to become Deputy Station Director, a new position created under the reorganization of Forest Service research administration. When Warren T. Doolittle, former Station Director, was called to Washington to serve as Director of Timber Management Research in September, Clark was appointed to succeed him.

R. Duane Lloyd was appointed to fill the position of Deputy Station Director. Lloyd had served for 3 years as Principal Recreation Scientist on the Forest Environmental Research staff at the Forest Service Washington headquarters.

Thomas E. Hamilton became Assistant Station Director for Planning and Application—a new position. Previously he had served as Assistant Station Director for Economics, Survey, Marketing, and Utilization.

Both Lloyd and Hamilton are stationed at the Experiment Station's headquarters at Upper Darby, Pa.

Under the Station reorganization, three Assistant Station Directors in charge of continuing research moved from Upper Darby to the field, closer to the programs they administer, the problems they must solve, and the people they serve.

Daniel M. Schmitt, formerly Assistant Director for Timber Management Research, now has headquarters at Durham, N. H. He has responsibility for research programs in Maine, New Hampshire, Vermont, Connecticut, Massachusetts, New York, and New Jersey.

Eldon W. Ross, formerly Assistant Director of Insect and Disease Research, is stationed at Delaware, Ohio. He is Assistant Station Director for research in Ohio and Pennsylvania.

A third post, at Morgantown, West Virginia, was filled by Samuel F. Gingrich, formerly a Project Leader at our Columbus, Ohio, laboratory. His research area covers projects in Kentucky, West Virginia, Maryland, and Delaware.

James L. Bean recently retired from his assignment as Program Manager for gypsy moth research, with headquarters at Hamden, Connecticut.

Isabel T. Duffy came to the Station from the Southern Station in New Orleans. She fills the Public Information Officer's post left vacant when Hal Marx transferred to Washington as Research Applications Staff Assistant.

# RESEARCH HIGHLIGHTS

We do not have space to describe the entire Station research program and the activities and accomplishments of all its projects; so we present here a few brief highlights of the Station's research activities and accomplishments.

## Regional and National Forestry Research Planning

Considering the wide variety of forestry issues today, how can we be sure that our research programs are directed toward the highest priority problems? Is the Station's program well coordinated with other forestry research in the Northeast? How do our studies contribute to solution of National research needs?

To help answer these questions, the Northeastern Station has joined with forestry schools in the Northeast to identify high-priority problems and to plan for future research activity. Fifteen special groups, made up of top scientists, have been asked to prepare a master plan for Northeastern forestry research in their particular areas of expertise. These plans will not only guide regional forestry research, but will also be used for National forestry-research planning.

## Pinchot Institute Program Going and Growing

As our population continues to grow, more and more attention has been turned toward managing our natural resources to fill the needs of people in urban and suburban environments. Research is needed to guide our planning and policy decisions. The Pinchot Institute for Environmental Forestry Research was established to help meet these needs.

The Pinchot Institute was established in 1970 to coordinate an interdisciplinary research program directed toward the improvement of urban environments through manipulation and management of urban forests and open space. The Institute provides a way of coordinating research efforts between universities and the Forest Service. Research is carried out by two Station research units at Amherst, Mass., and Pennington, N. J., and the Institute's Consortium for Environmental Forestry Studies. The Consortium is made up of nine universities in the densely populated regions of the Northeast. Consortium research planning is done through seven specialized workshop groups. Overall research efforts are coordinated through an executive committee of elected representatives from member institutions.

The Pinchot Institute Consortium has sponsored 68 studies of environmental forestry problems during the past 5 years. In 1974, $291,000 was contributed through research grants and cooperative studies to support 21 studies, covering a wide spectrum of problems in forest amenities, tree genetics, wildlife, recreation, and urban landscape values.

The Station and the Consortium are cooperatively sponsoring three symposia in 1975: (1) the Meaning of Natural Environments to Children (19-23 May, Washington, D. C. ); (2) Planning and Management of the Metropolitan Physical Environment (25-29 August, Syracuse, N. Y.); and (3) Selection and Breeding of Trees for Densely Populated Urban Areas (5-6 November, Washington, D. C.)

## Gypsy Moth Program Expanded

The gypsy moth research, development, and application program has received a helpful boost. Congress provided additional funds for fiscal year 1975 to assure that the program can be expanded and accelerated.

Objectives of the 4-year expanded program are (1) to implement the available technological improvements for reducing losses from and spread of the gypsy moth, and (2) to develop and evaluate new short- and long-term forest- and pest-management systems to effectively prevent, contain, and suppress infestations of gypsy moth.

Priorities have been set to assure that several new control techniques will be operational within 4 years. As each control method becomes operational, it will be added to the USDA integrated control system, designed to capitalize on the best features of each technique—and avoid environmental hazards.

## Population Dynamics and Ecology of Forest Insect Pests

A mathematical model for predicting dispersal of gypsy moth larvae suggests that most windblown larvae are deposited within ½ mile of their source and are not blown long distances. Intensive evaluation of *Blepharipa scutellata* R-D., an important parasite of gypsy moth, indicates that its effectiveness is limited by high overwinter mortality. A method for rearing this parasite in the laboratory has recently been developed.

## Milestones in Gypsy Moth Virus Research Program

In the gypsy moth virus program—seeking ways to use viruses to control gypsy moth populations — several important milestones were reached in 1974. The virus program was presented at an international meeting in Spain; and the Hamden gypsy moth nucleopolyhedrosis virus was adopted as the international standard for comparative purposes. Three required safety tests have been completed; all data indicate no adverse effects due to the virus. A large-scale mass production of the virus was completed, and successful production of the virus in a tissue-culture system has been demonstrated and is being evaluated. An aerial field test of the virus was conducted in Pennsylvania, with encouraging preliminary results. Effective working relationships have been developed with EPA, which will help implement the virus registration effort.

## Wood Borer Damages to Appalachian Oak

A study in West Virginia, Ohio, and Kentucky showed that oak borers cause damage evaluated at $24 for every 1,000 board feet of red oak factory-grade lumber produced. Total loss from wood-borer damage in standing sawtimber in the three-state area is estimated at half a billion dollars a year. Cumulative losses are due to the combined effects of such pests as the red oak borer, carpenterworm, and oak timberworm.

## Pheromone Developed in Battle to Control Bark Beetle that Carries Dutch Elm Disease

Suppression of Dutch elm disease has depended upon controlling the activities of the smaller European elm bark beetle, *Scolytus multistriatus*. Multilure, a synthetic aggregation pheromone for the beetle, has been developed in a cooperative effort by entomologists and chemists at the Station and the State University of New York at Syracuse. Pheromone-baited traps have already proved a superior tool for delineating the distribution of this beetle, detect its presence in new locations, and monitor its emergence patterns. The potential of mass-trapping elm bark beetles at pheromone-baited traps for massive reduction of beetle populations and suppression of Dutch elm disease incidence is now being evaluated.

## Forest Tree Foliage Removes Pollutants from Air

Research to determine the importance of trees in removing gaseous pollutants from the atmosphere demonstrated that both ozone and sulfur dioxide are rapidly removed from the air by the foliage of forest trees. This information, along with knowledge of sorption rates of several tree species, may be used by urban or freeway planners in positioning trees or greenbelts to reduce pollutant levels.

## Basic Biology: Meristems and Morphogenesis in Trees

We need more basic information about how new cells are formed by the meristems at the tips of shoots and in the cambium. Information about how the thin-walled new cells develop into wood and other tissues also is inadequate. This is part of the complex problem of morphogenesis. What controls the development of cells and tissues so that they assume

the shapes and functions of specific organs or parts while the whole organism develops into a tree of integrated form and function?

One approach to the problem is to isolate the microscopic apical meristems from shoot tips and to observe their growth and development in aseptic culture under laboratory conditions. After the technical difficulties of doing this had been overcome, it was found that meristems in culture release soluble substances that interact at a distance from the tissue to produce and deposit various materials related to the lignins and polysaccharides of wood. These procedures offer a new method of studying the synthesis of lignin and other wood components.

Another way of studying morphogenesis in trees is to read and interpret the record of cambial behavior that is encoded in the anatomy of wood cells. From a study of this type it was learned that, when coniferous trees are released and radial growth increases, there also is a sudden increase in height of rays. There is evidence that such increases in ray size may persist much longer than the stimulus that evoked them. This kind of basic biological information helps provide a scientific basis for development of intensive forest management procedures.

## Combining Economics with Silviculture in Selection Cutting

An individual-tree selection procedure, combining economic and silvicultural guidelines, was developed for nine hardwood species. One consideration in cut-or-leave decisions is: what is an acceptable rate of return?—2 percent? 4 percent? 6 percent? In practice this procedure is applied as a flexible diameter limit, using low, medium, and high rates of return for oak site indexes 60, 70, and 80. Other considerations in marking are growth rates and changes in log quality and tree vigor for a 10-year period.

## Patch Clearcutting and Northern Hardwood Ecosystems

Research at Hubbard Brook, New Hampshire, has thrown new light on aspects of northern hardwood ecosystems. For example, take patch cutting, which is often recommended to improve wildlife habitat and esthetic values. One question is how it affects evapotranspiration (a reduction in evapotranspiration means increased water yields downstream). Analyses of vegetation and soil-water potentials, climate, and plant anatomical characteristics indicate that a number of patch clearcuttings will not reduce evapotranspiration as much as a single clearcutting equivalent in size to the combined acreage of the patch cuttings.

## Use Small Land Units in Planning Timber-and-Wildlife Management

Some forests should be managed for the production of wildlife as well as timber. Because most wildlife species need two or more successional stages of forest in their habitat, maintaining relatively stable populations of these wildlife species throughout a forest rotation can best be assured by attaining a balanced distribution of age classes of trees throughout the forest. And because the home ranges of most wildlife species are relatively restricted, tree age-class distribution must be regulated by much smaller units of land than would be necessary for timber production alone. The key to successful regulation of tree age classes for combined timber and wildlife production is long-term planning of cutting schedules for *small* units of land. This will help stabilize wildlife populations. It also will permit determining how much management for wildlife benefits will reduce timber yields.

## Selection Cutting Requires Control of Diameter Distribution

Many people have the idea that sustained yield is automatic under any form of partial cutting in which trees are individually marked; but this is not true. True selection cutting for sustained yield requires continual control of the diameter distribution throughout the entire range of diameters desired. A paper has been written to show what is required to make selection cutting work, and to show that application of various misnamed types of "selection" cutting will result in wide fluctuations in timber yield. The kinds of forest in which sus-

tained yield is high priority is distinguished from those in which a less critical form of selection or group-selection cutting may be used. This should lead to a higher level of professional application of selection cutting.

## Fertilizing Cherry Seedlings Stimulates Early Flowering

Genetic improvement in forest trees is a slow process, due in part to the long time required for selected progeny to mature and produce seeds. In a study on the Allegheny National Forest in Pennsylvania, it was found that nitrogen and phosphorous fertilization of black cherry seedlings in a seed orchard stimulated early flowering just 4 years after planting. Fertilizers also improved survival and produced increases of 145 percent in basal area and 50 percent in height growth of some half-sib families. There were large differences in response among families. These results suggest that it may be possible to reduce the time required for cherry seed orchards to produce seed. Furthermore, the dramatic growth differences between some families suggest that it may be possible to select families that are especially responsive to fertilization for future intensive culture.

## Research Aids Maple Syrup Business

Maple—wood, sap, and syrup—is big business in Northeastern hardwood regions. Research by Station scientists at Burlington, Vermont, has helped to stimulate a gradual change from the independent producer-processor-retailer business to an industry that has distinct production, processing, brokerage, and retail functions. Three useful state-of-the-art publications related to sap production (including design and layout of plastic-tubing sap-collection systems), silvicultural prescriptions for converting natural stands to productive sugarbushes, and recommendations for storing sugar maple seeds to promote maximum germination, were published by the Station, the first two in collaboration with State and Private Forestry and extension foresters.

## Creating Habitat for Birds in Populated Areas

How does one manage woodlands to enhance bird-watching? Much relevant information is available, scattered in technical journals, but little in how-to-do-it form. So Station scientists have translated technical information into a practical guide for managing trails, sites, and plant species and growth stages with respect to area dimensions and design. They suggest managing for many birds of many different species, near trails and other human-activity centers, and for natural-looking nesting habitat.

## The Market for Recreation

Increased public awareness of outdoor recreation opportunities provided by forests has stimulated another kind of research—prediction of demand for outdoor recreation. Our scientists at Durham are leaders in research on the campground sector of recreation markets. They recently published a comprehensive bibliography of camping markets. They also collaborated in a two-part analysis of the campground market in the Northeast. The second part, covering the private sector, was published in 1974; it provides a complete evaluation of the current private campground market in the Northeast.

## New Tree and Log Grades for Hardwoods Tested

Before newly developed log and tree grades can be put into use, they must be tested for reliability and ease of application. The new hardwood tree grades have been tested on an independent sample of trees. A workshop was held at the Fernow Experimental Forest in West Virginia to explain the new tree grades and give the participants an opportunity to apply the grades in the field. Personnel from Research, State and Private Forestry, and the National Forest System participated.

## Forest Survey

Recent inventories in Vermont and New Hampshire revealed little change in forest-land area over the last decade. But per-acre grow-

ing-stock volume has increased in Vermont from 880 cubic feet in 1966 to 1,068 cubic feet, and in New Hampshire from 970 cubic feet in 1960 to more than 1,400 cubic feet. Annual net growth averaged 44 cubic feet per acre in New Hampshire and 21 cubic feet in Vermont. Vermont's lower growth rate resulted from poorer stocking in growing-stock trees. In both States, growth exceeded removals by more than 2-to-1. The latest inventory of Vermont reinforces 1965 findings that considerable stand improvement is required if the State's forests are to produce at full potential.

## Availability of Timber

As part of the survey of Vermont and New Hampshire, a study was made to obtain information about the owners of private land, how much of their timber is available for harvesting, what other uses they have for their land, and their attitudes about and plans for their land. One finding was that, though less than 20 percent of the owners in these States had harvested timber from their forest land, the acreage they owned was about two-thirds of the total private commercial forest land. These and other findings from this canvass should provide valuable guidance to foresters and other resource managers in reaching the forest landowner and meeting his needs.

## New Markets for Bark

In the past, bark produced at Appalachian sawmills and veneer mills was burned or dumped as a waste product. But during the 1970s a variety of markets have been developed for bark residues. Our research has shown that, for producing steam, bark costs less than any other industrial fuel. To aid in the development of bark markets and uses, our researchers have developed yield tables for bark residues; the tables provide bark-residue weights per log (by log-scale volume) for eight important Appalachian species.

## Better Sawing Method for Low-Grade Logs

At most Appalachian sawmills, low-grade hardwood logs cannot be processed efficiently by conventional grade-sawing methods. Consequently, live-sawing (sawing a log through-and-through, without turning) has been studied as an alternative method for mills that do not have resaw equipment. The live-sawing method results in significant gains over grade-sawing in lumber production rates, overrun, and average lumber value.

## Engineering Research in Timber Harvesting

Harvesting hardwood timber from steep Appalachian slopes causes objectionable damage to the environment in many places. Poorly constructed logging roads contribute to erosion and sedimentation. On logging jobs where many roads are constructed, the area as seen from a public road is unsightly. One approach toward alleviating this problem is the use of skyline cable logging. A small skyline system tested on the Fernow Experimental Forest showed promise for minimizing this environmental problem.

## Computer Program Developed for Whole-Tree Chipping System

By using a whole-tree chipping system, more wood fiber can be produced from every acre of forest harvested. But integrating a whole-tree chipper into a logging system is difficult. So many variables must be considered to achieve balance, minimum cost, and efficient operation. A computer program has been developed for doing this. The best cost picture results when the capabilities of fellers, skidders, and trucks are balanced with the capability of the chipper.

## Research on Reclaiming Mined Lands

Research, emphasizing reclamation of surface-mined areas in the Appalachians, continued to add to our knowledge of the best ways of placing mine spoils and of revegetating them.

Highest yields of sediment from surface-mined watersheds occurred during the first 6 months after mining. They diminished to low levels within 3 years. Information on the physical and mechanical properties of specific spoil

materials can be used to plan placement of mine spoil so that outslopes of spoil banks are more stable. Unstable banks contribute to erosion and sedimentation.

Getting herbaceous cover growing on mine spoils is an important way of reducing erosion and sedimentation. Studies in Kentucky and West Virginia have shown that herbaceous cover can be established within 60 days of seeding. Seeding can be done any time between March 1 and October 15.

It has been found that mulches and soil stabilizers help control erosion directly but are not essential for getting vegetation established on surface-mined areas in Kentucky and West Virginia. Lime, fertilizer, and mulch *were* found to be necessary for establishing herbaceous cover on refuse banks from bituminous deep mines in Pennsylvania.

When planted on the same areas as tree seedlings, grasses and herbs did not affect survival of the young trees. However, they did suppress tree growth until the legumes became the dominant herbs. Then tree growth was enhanced.

In studies of planting containerized tree seedlings, plastic tubelings were found to be more susceptible to frost-heaving than peat pots or Jiffy-7 containers.

Application of fly-ash to acid mine spoils lowered spoil density, neutralized acidity, increased plant-available phosphorous, and increased subsurface moisture, all of which should help plants grow on these sites.

# PUBLICATIONS

**in 1974 by staff members and cooperators of the Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture**

In 1974, Station personnel and their cooperators were credited with more than 300 publications—in scientific and trade journals, popular periodicals, Department of Agriculture publications, symposium proceedings, and Station papers, notes, and general technical reports.

Publications and reprints that are available, in limited numbers, are marked with asterisks (*). If you want a publication, ask for it by author's name, date, and title. Address requests to the Northeastern Forest Experiment Station, 6816 Market Street, Upper Darby, Pa. 19082.

*Arner, Stanford L.

1974. **Profile—A computer program for displaying the geometric relationships of the responses in a factorial design.** USDA For. Serv. Res. Pap. NE-288. 21 p., illus.

Profiles are plots of the sample means of each level of one factor at each level of one or more of the other factors in an experiment. The author presents a computer program that produces profiles of the experimental means and discusses the interpretation of these profiles.

Aubertin, G.M.

[1974] **Problems and techniques in sampling water for analysis.** Univ. Ky. Symp. on Use of Small Watersheds in Determining Eff. of For. Land Use on Water Qual. Proc.: 1-9. Lexington.

A discussion of some problems encountered and techniques utilized in obtaining stream and lake-water samples for physical and chemical analysis.

*Aubertin, G.M., and J.H. Patric.

1974. **Water quality after clearcutting a small watershed in West Virginia.** J. Environ. Qual. 3(3) : 243-249.

A 34-hectare gaged watershed on the Fernow Experimental Forest, Parsons, West Virginia, was conventionally clearcut in 1969. Streamflow increased 20 cm during the first year after cutting, but rapid and luxuriant revegetation reduced the flow increase to only 6.4 cm during the second year. Water quality remained high. Success in avoiding damage to water quality was attributed to careful road management, retention of a forest strip along the stream, and rapid, lush vegetative regrowth after clearcutting.

*Auchmoody, L. R.

1974. **Nutrient composition of blades, petioles, and whole leaves from fertilized and unfertilized yellow-poplar.** USDA For. Serv. Res. Note NE-198. 5 p.

Nitrogen (N) and phosphorus (P) concentrations in leaf blades and petioles obtained from three fertilized and three unfertilized yellow-poplar sample trees were determined annually during a 4-year period. Concentrations were substantially higher in blades than in petioles. Fertilization increased N and P concentrations in blades, but petioles showed only a slight increase in N and a decrease in P. Because blades were more responsive to changes in external nutrient supply than petioles, and because fertilization affected the composition of blades and whole leaves unequally, blades give a more sensitive and accurate measure of nutrient concentration than petioles or whole leaves.

Barger, Jack H., and Kenneth Helrich.

1974. **Evaluation of aerial applications of Gardona for gypsy moth suppression.** (Abstr.) Entomol. Soc. Am. North Cent. Branch Annu. Meet. 29: 179-180.

In a 1972 field test, Gardona sprayed by helicopter failed to affect gypsy moth egg-mass counts or defoliation estimates. Apparently this was because the formulation failed to

adhere to foliage, the area received above-average precipitation, the spray deposit and residue were highly variable, and the chemical was insufficiently toxic under field conditions.

*Barnard, Joseph E., and Teresa M. Bowers.
1974. **A preview of New Hampshire's forest resource.** USDA For. Serv. Res. Note NE-197. 5 p.

Forest continues to be the dominant land use in New Hampshire. Three inventories of the State between 1948 and 1973 showed little change in the total forest area but significant shifts in forest type and stand size. Average volume per acre has increased to over 1,400 cubic feet and 2,785 board feet. Growth continues to exceed removals.

*Barnard, Joseph E., and Teresa M. Bowers.
1974. **A preview of Vermont's forest resource.** USDA For. Serv. Res. Note NE-196. 6 p.

Forest land occupies 75 percent of the total land area in Vermont. Nearly one-half of this forest land is occupied by the beech-birch-maple forest type. The inventory data show volume increasing but at a lower rate than in neighboring states. This is due to large losses from cull and mortality. Total growing-stock volume is now 4.7 billion cubic feet.

Barnard, J.E., and Larry Letourneau.
1974. **Data processing systems for large inventories.** Soc. Am. For. Inventory Work. Group Workshop Proc.: 141-149. Fort Collins, Colo.

Inventory data processing is viewed as an integral part of forest inventory design. FINSYS, a specific automatic data processing system for processing forest inventory data, is described. The development, use, and flexibility of this system are demonstrated with examples.

Bate, L.C., W.S. Lyon, and E.H. Wollerman.
1974. **Gold tagging of elm bark beetles and identification by neutron activation analysis.** Radiochem. Radioanal. Lett. 17(1): 77-85. Akademiai Kiado, Budapest.

Living elm bark beetles briefly immersed in an aqueous solution of gold chloride 0.01 percent and placed on elm twigs (their natural food) for 12 days showed survival of 47 percent as compared with 76 percent survival among controls. Effect of this labelling on flight of the beetles must be determined before this method can be used for estimating beetle populations.

Beaton, John A.
1974. **Sensitometry—its uses.** [USDA For. Serv. SE. Area S&PF] Seed X-ray Symp. Proc.: 85-92, illus. Macon, Ga.

A simple system is described that explains the use of sensitometry for (1) film selection based on contrast enhancement and (2) optimum film performance by adjusting exposure density. Relative film speeds, methods of exposure correction, and means of describing exposures are also discussed.

*Bevins, M.I., T.L. Brown, G.L. Cole, K.J. Hock, and W.F. LaPage.
1974. **Analysis of the campground market in the Northeast. Report II. Privately owned areas.** Vt. Agric. Exp. Stn. Bull. 679. 29 p.

The results of a 1971 interview survey of 529 commercial campground operators in 12 Northeastern States, including the characteristics of successful and unsuccessful campground enterprises: size, location, facilities, services, costs, and returns. Also includes a financial analysis of 292 enterprises and the relationship between gross income and 30 selected factors. Describes marketing and pricing practices of campgrounds and discusses the industry's growth prospects.

Blum, Barton M.
1974. *ARALIA* **L.: Aralia.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 220-222, illus.

A summary of the flowering, fruiting and seeds of the genus Aralia, with notes on collection, extraction, and storage; pregermination treatments; and nursery practice.

Blum, Barton M., and Arnold Krochmal.
1974. *EPIGEA REPENS* **L.: Trailing arbutus.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 380-381, illus.

A summary of growth habit, distribution, and use; flowering and fruiting; collection of fruits and extraction and storage of seeds; germination; and nursery and field practices.

*Blyth, James E., and James T. Bones.

1974. **Pulpwood production in the Northeast and North Central States for 1973.** North. Logger 23(3) : 16.

Pulpwood production between 1972 and 1973 increased 20 percent in the 21-State area, and all subregions (New England, Middle Atlantic States, Central States, and Lake States) contributed significantly to the higher output. These statistics and others resulted from a complete canvass of woodpulp mills conducted annually by the Forest Service Experiment Stations in the East. The article contains 1973 pulpwood statistics by States and sources of pulpwood, and the number of mills that were operating.

*Bones, James T., and David R. Dickson.

1974. **The veneer industry in the Northeast—1972.** USDA For. Serv. Resour. Bull. NE-33. 13 p., illus.

From a survey of veneer producers in the Northeast in 1972, veneer-log production and receipts by States and species, and log shipments between States and regions are presented. Comparisons are made with a similar survey made in 1968. A current list of northeastern veneer manufacturers is included.

*Bones, James T., and David R. Dickson.

1974. **Pulpwood production in the Northeast, 1973.** USDA For. Serv. Resour. Bull. NE-37. 19 p., illus.

An annual report based upon canvasses of pulpwood production in the Northeast, containing data about pulpwood production from roundwood in the 14 Northeastern States by counties and species groups, and pulpwood chip production from plant residues. Comparisons are made with the previous year's production data. Trends in pulpwood production for the past 11 years are shown. Also included is a list of the woodpulp mills that were operating in the region in 1973.

*Bones, James T., N. Engalichev, and W. G. Gove.

1974. **The timber industries of New Hampshire and Vermont.** USDA For. Serv. Resour. Bull. NE-35. 25 p., illus.

The results of a complete survey of the timber industries in New Hampshire and Vermont. The report contains statistics about roundwood production and receipts, and production and disposition of the manufacturing residues that result. Comparisons are made with the most recent previous surveys, and trends in industrial wood output are noted.

Bonner, F. T., and John A. Crossley.

1974. *VITIS LABRUSCA* **L.: Fox grape.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 853-854, illus.

A revision and updating of information on this genus from the 1948 Woody Plant Seed Manual. Distribution, use, reproduction, collection of fruits and seeds, germination, and nursery practices are discussed; and fruit, seeds, and germination are illustrated.

Bormann, F.H., G.E. Likens, T.G. Siccama, R.S. Pierce, and J.S. Eaton.

1974. **The export of nutrients and recovery of stable conditions following deforestation at Hubbard Brook.** Ecology Monogr. 44(3) : 255-277.

Deforestation and growth repression for 3 years increased particulate matter export to a maximum of 38 metric tons $km^{-2}yr^{-1}$—about 15 times export from the hardwood forested ecosystem. Export was exponential with the greatest increase the third year. The average ratio of net annual export of dissolved substance to particulate matter was 2.3 in the mature ecosystem and $> 8.0$ during the first 2 years after deforestation. Nutrient flux and erosion losses returned to previous levels with increased biotic regulation.

Brodie, John E., and Jean Nolley.

1974. **Maryland's primary wood industry: a utilization summary and directory.** Md. For. Serv. Dep. Nat. Resour. 59 p. Annapolis.

A primary wood-industry directory useful to buyers and sellers of roundwood, secondary manufacturers, and industrial planners. A resumé of the industry's functional characteristics and concentration is also provided. The directory includes names and addresses of sawmills, loggers, concentration yards, and 10 other primary wood industries in Maryland. Sugar maple producers and pallet mills are also listed. Detailed information in-

cludes special equipment used, products purchased and sold, principal species sawn, and annual production.

*Campbell, Robert W.

1974. **Relation between overstory composition and subsequent defoliation by the gypsy moth.** J. For. 72: 142-143, illus.

The percentage of favored food in the overstory was closely related to the subsequent level of defoliation by the gypsy moth. Thus the silvicultural recommendations that are based on the "favored-food" theory may be valid with respect to abating the damage done to the forest by this insect.

*Campbell, Robert W.

1974. **Relationships between overstory composition and gypsy moth egg-mass density.** USDA For. Serv. Res. Note NE-191. 6 p.

Most of the silvicultural recommendations for reducing the hazard of gypsy moth outbreaks have been based in part on the premise that gypsy moth density levels are related closely to the proportion of favored food trees in the overstory. This premise did not prove to be true for a series of plots observed in eastern New England between 1911 and 1931.

*Campbell, Robert W., and Joseph P. Standaert.

1974. **Forecasting defoliation by the gypsy moth in oak stands.** USDA For. Serv. Res. Note NE-193. 7 p., illus.

A multiple-regression model is presented that reflects statistically significant correlations between defoliation by the gypsy moth, the dependent variable, and a series of biotic and physical independent variables. Both possible uses and shortcomings of this model are discussed.

Collins, E.B., and K.C. Elliott.

1973. **Possible power sources for forest industry use.** W. Va. Univ. Agric. Exp. Stn. 70 p. Morgantown.

A review of different methods of power production, both old and new, including solar energy, fuel cells, rotary engines, gas and diesel engines, external combustion engines, and battery power. The stage of development of each power unit and current or future applications as stationary or mobile sources of power are discussed.

*Conner, R.N., and H.S. Crawford.

1974. **Woodpecker foraging in Appalachian clearcuts.** J. For. 72: 564-566.

In mixed oak stands, downy and hairy woodpeckers ate insects they found under the bark of abundant logging debris left 1 year after clearcutting. Flickers ate ants and fruits found on the ground in an area clearcut 5 years previously. A 12-year-old clearcut area was used only occasionally by all these birds. A mature uneven-aged stand was used substantially by downy, hairy, and pileated woodpeckers, but not by the common flicker.

Core, Earl L.

1974. **Brambles.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 16-19.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Core, Earl L.

1974. **Red mulberry.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 106-107.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Core, Earl L.

1974. **Spireas.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 132-133.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Crawford, H.S. and I.R. Porter.

1974. **Upland hardwood-bluestem.** *In* Range resources of the South. Ga. Agric. Exp. Stn. Bull. NE-9: 17-19.

The upland hardwood-bluestem type occupies about 46 million acres in parts of Tennessee, northern Mississippi, southern Missouri, northern Arkansas, and eastern Oklahoma and considerable acreage in several more northern states. Oaks are the most abundant tree species, composites the most abundant forbs, and little bluestem, big bluestem, Indiangrass, switchgrass, and native legumes

the most abundant cattle forage plants in late spring and early summer. Where successfully established, fescue provides cool-season forage.

Cromer, Jack I.

1974. **American bittersweet.** *In* Shrubs and vines for Northeast wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 10-11.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Crossley, John A.

1974. *VACCINIUM* **L.: Blueberry.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 840-843, illus.

A new genus added to the revision of the 1948 Woody Plant Seed Manual. Distribution, use, reproduction, collection of fruits and seeds, germination, and nursery practices are discussed.

Crossley, John A.

1974. *SOLANUM DULCAMARA* **L.: Bitter nightshade.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 777-778, illus.

A revision and updating of information on this genus from the 1948 Woody Plant Seed Manual. Distribution, use, reproduction, collection of fruits and seeds, germination, and nursery practices are discussed; and fruit, seeds, and germination are illustrated.

Crossley, John A.

1974. *MALUS* **Mill.: Apple.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 531-534, illus.

A revision and updating of information on this genus from the 1948 Woody Plant Seed Manual. Distribution, use, reproduction, collection of fruits and seeds, germination, and nursery practices are discussed; and fruit, seeds, and germination are illustrated.

Curtis, Willie R.

1974. **Sediment yield from strip-mined watersheds in eastern Kentucky.** Natl. Coal Assoc. Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc. 2: 88-100. Louisville, Ky.

Measurements of sediment accumulation in debris basins below surface-mined lands in eastern Kentucky show highest sediment yield during the first 6 months after mining. The erosion rate diminishes to fairly low levels within 3 years. Methods of mining and handling spoil affect sediment yield, as does the speed with which vegetative cover is established.

Curtis, Willie R.

[1974] **Introduction.** Univ. Ky. Symp. on Use of Small Watersheds in Determining Eff. of For. Land Use on Water Qual. Proc. Lexington.

We are leaving a period of land surplus and entering a period of increased competition for land, resulting in increased needs for management of both these lands and associated water resources. It is not enough to say certain land uses will not be allowed to impair water quality; rather, alternatives with predictable consequences must be provided. Much of the data for determining such alternatives can be obtained from study of small watersheds.

Davidson, Walter H.

1974. **Reclaiming refuse banks from underground bituminous mines in Pennsylvania.** Natl. Coal Assoc. Symp. Mine and Prep. Plant Refuse Disposal Proc. 1: 186-199. Louisville, Ky.

Results of studies on the composition of waste from underground bituminous mines and techniques for establishing vegetation on mine-waste piles. Chemical and physical analyses of spoil from 79 different sites showed such wide divergence of characteristics that no trends could be established. Field plantings on five sites, using lime, fertilizer, and hardwood bark mulch as amendments, showed that all three were necessary to establish herbaceous cover. Tree survival did not appear to be greatly influenced by the amendments. Weeping lovegrass, K-31 tall fescue, and Korean lespedeza were tested. Red pine was the only tree species used.

Davidson, Walter H., and Edward A. Sowa.

1974. **Early attempts to vegetate coal-mine spoils with container-grown seedlings.** North Am. Containerized For. Tree Seedling Symp.: 372-376. Great Plains Agric. Counc. Publ. 68, Denver, Colo.

Afforestation attempts with Ontario and other plastic tubelings indicated that frost-heaving can be extremely detrimental on bituminous coal-mine spoils. Of the containers tested, peat pots and Jiffy-7s were found to be most resistant to frost-heaving. Compared with bare-root seedlings, seeded red pines in peat pots and Jiffy-7 containers performed well.

*Davidson, Walter H., and Edward A. Sowa.
1974. **Container grown seedlings show potential for afforestation of Pennsylvania coal-mine spoils.** Tree Planters' Notes 25 (4) : 6-9.

Afforestation attempts with Ontario-type and other plastic tubelings indicated that frost-heaving can be extremely detrimental on coal-mine spoils. Other types of containers—peat pots and Jiffy-7s—were found to be more resistant to frost-heaving. Compared with bare-root seedlings, seeded red pines in these containers survived and grew equally well.

Davis, Grant.
[1974] **Team approach to watershed ecosystem analysis.** Univ. Ky. Symp. on Use of Small Watersheds in Determining Eff. of For. Land Use on Water Qual. Proc.: 79-82. Lexington.

Environmental research has shifted from a piecemeal approach to one of ecosystem analysis through multidisciplinary team efforts. This has resulted both from a change in philosophical viewpoint and advances in computer science that makes possible use of complex models. Small watersheds are ideal ecological units for such a multidisciplinary approach to ecosystem analysis. Forested watersheds that have been partially strip-mined are useful examples for developing complex ecosystem models.

DeGraaf, Richard M., and Jack Ward Thomas.
1973. **A strategy for wildlife research in the city—the Forest Service program.** Northeast. Wildl. Conf. Trans. 29: 29-44.

The management of city habitats for wildlife production (especially songbirds and non-game mammals) for aesthetic enjoyment will require extensive coordinated research to provide guidance for such efforts. A generalized framework for such research is suggested. Studies being conducted by the Forest Service research unit at Amherst, Mass., are described.

DeGraaf, Richard M., and Jack Ward Thomas.
1974. **A strategy for wildlife research in urban areas.** *In* Wildlife in an urbanizing environment: 53-56. Univ. Mass. Holdsworth Nat. Resour. Cent. Plann. and Dev. Ser. 28. Amherst.

Control of pest species has been the main application of wildlife management in urban areas, but now a new research and management responsibility emerges; the provision of wildlife solely for enjoyment. A research program is proposed in three broad areas: (1) human preferences, (2) habitat requirements, and (3) human-wildlife interaction.

DeGraaf, Richard M., and Jack Ward Thomas.
1974. **A banquet for the birds.** Nat. Hist. 83(1) : 40-45, illus.

A study of the economics of feeding wild birds revealed that in 1971, residents of Amherst, Massachusetts, spent an average of $8.80 per family for this activity. An estimated $3.4 million was spent on this activity in Massachusetts in 1971. Data from five major cities are presented (New York, Boston, St. Louis, Milwaukee, and Cleveland) and also a discussion of the possible ecological effects of bird-feeding.

*Despard, Thomas L.
1974. **Avoid problem spoils through overburden analysis.** USDA For. Serv. Gen. Tech. Rep. NE-10. 4 p., illus.

During strip-mining of coal and subsequent grading operations, indiscriminant placement of toxic overburden strata at the spoil surface creates reclamation problems that are difficult and expensive to correct. Evaluation of overburden material before mining is begun is suggested as the most reliable means of predicting spoil quality and devising a reclamation plan. This can best be accomplished by core-drilling the proposed area and submitting the recovered core samples to a laboratory for chemical analysis. Color, pyrite content, and pH are field

guides used to determine the potential toxicity of exposed overburden strata.

Dochinger, Leon S.

1974. **An assessment of air-pollution injury to American forests.** Sylwan 9: 63-68.

Ozone, fluorides, and sulfur dioxide cause most of the air-pollution problems in American forests. The nature and effects of these pollutants and minor aerial phytotoxicants are discussed.

*Dochinger, Leon.

1974. **Air pollution problems in nurseries.** New Horizons: 1-5. Hortic. Res. Inst., Washington, D.C.

Chronic air pollution can threaten green survival and cause imbalances in the composition of plant communities. Major research investigations are suggested along with the need for cooperative action among private and government agencies for protecting nursery and ornamental crops in a polluted environment.

*Donley, David E.

1974. **Wood borer losses in Appalachian oak.** South. Lumberman 229(2848): 115, 116, 118, illus.

Cooperative research between entomologists of the USDA Forest Service and Appalachian lumber producers reveals that wood borers are responsible for $50,000,000 worth of oak quality loss each year in West Virginia, Kentucky, and Ohio. This estimate of loss came from double-grading of lumber produced from mill-run logs taken from 14 timber-harvest areas. Lumber grade changes caused value reductions of $25 M board feet for Ohio oak, $19 M for West Virginia oak, and $26 M for Kentucky oak. Borer losses to standing timber in the three-state area will add up to almost half a billion dollars.

*Donley, David E., C.J. Hay, and J.R. Galford.

1974. **Wood borer impact on Ohio oak.** Ohio Woodlands 12(2): 4-5 14, illus.

Annual losses of between $2,000,000 and $3,000,000 to oak products in Ohio are being caused by a complex of wood-boring insects. By 1972 lumber values, borers reduce the value of factory-grade red oak lumber some $24 per thousand board feet of lumber produced. Ohio's white oak cooperage value is reduced about 7 percent by borers. Insects most responsible for these losses have been identified as the red oak borer, the white oak borer, the oak timberworm, and two species of carpenterworms.

*Donnelly, John R.

1974. **Shoot size significantly affects rooting response of sugar maple softwood cuttings.** USDA For. Serv. Res. Note NE-184. 4 p., illus.

Three hundred softwood cuttings were collected from each of three mature sugar maple trees to test the effect of shoot size on adventitious root formation. One of the trees was a good rooter (61 percent rooted); one was a poor rooter (19 percent); and the third was a non-rooter (1 percent). Long cuttings rooted better than short cuttings and thick cuttings tended to root better than thin ones for one study tree; for the other tree, relative shoot thickness within a length class had no effect on rooting.

*Donnelly, John R., and Harry W. Yawney. [1973]. **Some factors associated with vegetatively propagating sugar maple by stem cuttings.** Int. Plant Propag. Soc. Annu. Meet. Proc. 1972: 413-430, illus.

This report summarizes results of several studies designed to stimulate rooting and overwintering survival of sugar maple stem cuttings collected from mature trees. Results indicated that: (1) timing collection of cuttings is critical for maximum rooting response; (2) rooting response is directly correlated with thickness and length of cuttings; (3) hormone treatments showed mixed responses between cuttings collected from different trees; (4) watering potted rooted cuttings during winter storage with sugar and nutrient solutions did not increase overwintering survival; and (5) overwintering survival appears to be correlated with rooting vigor.

Donohoe, Robert W.

1974. **Sweet crab apple.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 29-31.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Donohoe, Robert W.

1974. **American hornbeam.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 86-88.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Doolittle, W.T.

[1974] **Some thoughts on the nature of watershed research needed for environmental policy decisions.** Univ. Ky. Symp. on Use of Small Watersheds in Determining Eff. of For. Land Use on Water Qual. Proc.: 83-87. Lexington.

Public concern and Federal legislation have brought about requirements for more intensive investigation of the impact of man's activities on his environment. Forest management is one area that has come under close scrutiny. Much additional research needs to be conducted on the environmental effects of forestry practices, and these needs are cited in detail. In addition, the desirability of establishing regional environmental programs is outlined, and the necessity of interagency cooperation and communication is stressed.

Dorn, Donald E., and L.R. Auchmoody.

1974. **Scheduling timber cutting for sustained yield of wood products and wildlife.** Timber-Wildl. Manage. Symp. Proc.: Mo. Acad. Sci. Occas. Pap. 3: 33-43.

If you want to manage a forest for long-term sustained yield of both timber and wildlife, this paper explains one way to go about it. The key is careful planning of cutting schedules for relatively small units of land.

Dorn, Donald E., and L.R. Auchmoody.

1974. **Progress report: Effects of fertilization on vegetative growth and early flowering and fruiting of seed orchard black cherry.** Northeast. For. Tree Improv. Conf. Proc. 21: 6-18, illus.

Nitrogen and phosphorous fertilization of seedlings 2 years after planting in an Allegheny National Forest seed orchard containing 17 half-sib black cherry families has shown that fertilization reduced mortality, increased growth as much as 145 percent, and promoted early flowering in some families. The growth response varied dramatically among families, suggesting that responsiveness to fertilizers will be an important selection criterion in further genetic improvement work with black cherry.

Eabry, Steve.

1974. **Mountain-ashes.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 98-101.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

*Echelberger, Herbert E.

1974. **Poor "Promotion-itis"?** J. Travel Res. 12(3): 5-6, illus.

Ski areas that cater to local skiers are receiving a poor return on investments in radio, television, and newspaper advertisements. Managers wanted to know how the effectiveness of their promotion programs could be improved. Types of advertising easily recalled by skiers and the effect of knowledge of skier origin and characteristics provide managers with a basis for developing more productive promotion campaigns.

Echelberger, Herbert E.

1974. **Environmental perception and urban forestry.** Univ. Wis. Urban For. Conf. Proc.: 17-28, illus.

Management of urban forests must reflect the social needs of the clientele as well as the biological needs of the stand. Knowledge of urban forest resources, urban forest purposes, and urban forest user expectations is needed during the formulation of urban forest-management policy. Man's perception of and preferences for natural environments are reviewed, followed by description of a study under way to measure viewer reactions to several timber-harvesting techniques.

Echelberger, H.E.

1974. **Timber management and aesthetics: a dilemma.** N. Y. For. 31(2): 21-23.

The impact that logging has on the beauty of a forest is one reason why foresters are questioned about the wisdom of some of their management techniques. A search for ways to improve the visual and physical conditions of a forest after a logging operation is described. A contribution to alleviating the

problem of timber management lies in development of a better local market for at present unmarketable logging residue.

*Echelberger, Herbert E., Daniel H. Deiss, and Douglas A. Morrison.

1974. **Overuse of unique recreation areas: a look at the social problems.** J. Soil and Water Conserv. 29(4): 173-178, illus.

A survey of skiers and hikers in Tuckerman Ravine in the White Mountain National Forest of New Hampshire revealed that different user populations perceive overuse of the area in different ways. Users were aware of their impact on each other. Attitudes toward five management alternatives to relieve the overuse problem were explored. Deterioration in the quality of experience provided by unique recreational areas such as Tuckerman Ravine are discussed. The Forest Service has limited overnight use to the carrying capacity of the open-faced shelters in the ravine.

Fay, Stephen, and R.E. Leonard.

1974. **Back-country research in the Northeast.** Maine For. Rev. 5: 16.

Areas accessible primarily by foot-path are increasing in importance for hiking, cross-country skiing, snowmobiling, and trail-biking. A research program begun by the Forest Service in 1972, concerned with the problems of back-country management, is briefly described.

Federer, C. Anthony.

1974. **Young vs. old forests.** [Letter to the editor.] Am. For. 80(7): 5.

The author disputes several points made by Fred C. Simmons in articles about wilderness in the East. There is no scientific evidence for differences in streamflow quantity or air quality between old forest and young forest. We do not need vigorous forests to produce oxygen.

Federer, C. Anthony, and Glendon W. Gee.

1974. **Tree water stress in relation to water yield in a hardwood forest.** Univ. N. H. Water Resour. Res. Cent. Res. Rep. 7. 30 p.

Stomatal resistance, xylem potential, soil-water potential, stem diameter, net radiation, air temperature, humidity, and wind were measured through a summer in a northern hardwood forest and on sunny and shady edges of clearings. Stomatal resistance was also related to phenology in spring and autumn. The measurement of stomatal resistance is an important new tool for studying the water relations of hardwood forests.

Federer, C.A., and G.W. Gee.

1974. **Diffusion resistance and xylem potential in stressed and unstressed northern hardwood trees.** (Abstr.) Agron. Abstr. 1974: 11.

Daytime stomatal resistance of mature trees in New Hampshire averaged 2.5 s/cm for *Betula alleghaniensis*, 3.0 s/cm for *Acer saccharum*, and 3.4 s/cm for *Fagus grandifolia*. This implies the possibility of different transpiration rates among the species. When rain was prevented from entering the soil for 3 weeks, stomata closed partially during the day, presumably limiting transpiration and growth.

*Ferguson, Roland H., and Carl E. Mayer.

1974. **The timber resources of Delaware.** USDA For. Serv. Resour. Bull. NE-32. 42 p., illus.

A statistical and analytical report of the second forest survey of Delaware. Trends in forest-land area, timber volume, annual growth, and timber removals are discussed. Timber-products output by forest industries, based upon a canvass of industries in 1970, and the importance of timber to the State's economy are also discussed. The report includes an outlook for timber supplies during the next 30 years and a discussion of forest-management opportunities.

*Ferguson, Roland H., and Carl E. Mayer.

1974. **The timber resources of New Jersey.** USDA For. Serv. Resour. Bull. NE-34. 58 p., illus.

A statistical and analytical presentation of the second forest survey of New Jersey. Trends in forest-land area, timber volume, annual growth, and timber removals are discussed. Timber-products output by forest industries, based upon a canvass of industries in 1970, and the importance of timber to the State's economy are also discussed. The report includes an outlook for timber supplies during the next 30 years and a discussion of forest-management opportunities.

Frank, Robert M.

1974. **Options for and probable benefits of timber stand improvement in Maine.** Maine For. Rev. 6: 2-4.

A world and local view of the timber supply and the potentials for improvement in Maine through timber-stand improvement. Potentials for improvement are based on early results obtained from long-term silvicultural studies being conducted on the Penobscot Experimental Forest. Conditions related to reduction in cull trees, reduction in the mortality rate, and changes in species compositions are featured.

Frayer, W.E., and J.E. Barnard.

1974. **Experience with sampling with partial replacement in the United States.** *In* IUFRO Subject Group S4.02 June 1973 Meet. (Nancy, France) Proc. vol. 2. 7 p.

The background of Sampling with Partial Replacement (SPR) is described briefly. Experience data are presented from several areas of the United States, showing correlation coefficients for regression estimators of current volume. Other advantages of SPR are noted, and the completeness of the sampling system, including available ADP, is discussed.

Fulton, John R.

1974. **Pin cherry.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 26-28.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Furnival, George M., and Robert W. Wilson, Jr.

1974. **Regression by leaps and bounds.** Technometrics 16: 499-511, illus.

The authors describe several algorithms for computing the residual sums of squares for all possible regressions with what appears to be a minimum of arithmetic (less than six floating-point operations per regression) and show how two of these algorithms can be combined to form a simple leap-and-bound technique for finding the best subsets without examining all possible subsets. The result is a reduction of several orders of magnitude in the number of operations required to find the best subsets.

Gabriel, William J.

1974. **Phenotypic selection of sugar maples for superior sap volume production.** Northeast. For. Tree Improv. Conf. Proc. 21: 19-26, illus.

The program for selection of superior sap volume followed the basic concepts developed earlier in selecting for superior sap-sugar production in sugar maples. Selection work was scheduled for Maine, New Hampshire, Vermont, Massachusetts, New York, Pennsylvania, Ohio, Michigan, and Wisconsin. Results of the first year of operation are presented. Seven states reported making 55 field selections from 2,375 trees tested in 38 different sugar-bushes. The program will be continued into the 1975-76 sugaring seasons.

Gabriel, William J.

1974. **A search for superior maples.** Natl. Maple Syrup Dig. 13: 16-17.

Locating superior sugar maple trees is the first step in the program for genetic improvement in sap production. The author asks sugarbush operators to report trees that they believe are superior sap producers.

*Galford, Jimmy R.

1974. **Some physiological effects of temperature on artificially reared red oak borers.** J. Econ. Entomol. 67: 709-710.

*Enaphalodes rufulus* (Haldeman) was artifically reared at 21.1, 26.7, and 32.2°C. Larvae reared at 21.1°C required about 50 days longer to develop than larvae reared at 26.7 or 32.2°C and were much smaller. Females reared at 21.1°C produced half as many eggs as females reared at 32.2°C. Most of the larvae entered diapause soon after reaching their maximum weight. A cold treatment was required to break diapause.

*Garrett, David

1974. **The energy crisis: what it means to you as a producer.** Natl. Maple Syrup Dig. 13(1): 12-16.

This study evaluated maple syrup processing costs and product price as affected by increased cost of No. 2 fuel oil. A price rise from 18 to 36 cents resulted in a 75-cent increase in costs of producing a gallon of syrup. Prices of maple syrup had to be increased 10 to 15 percent to compensate for increased costs. The results were used by

industry in establishing new price guidelines for 1975.

*Gatchell, Charles J., and Jarvis D. Michie.
1974. **Pendulum impact tests of wooden and steel highway guardrail posts.** USDA For. Serv. Res. Pap. NE-311. 20 p., illus.

Impact strength characteristics of southern pine, red oak, and steel highway guardrail posts were evaluated in destructive impact testing with a 4,000-pound pendulum at the Southwest Research Institute. Effects were recorded with high-speed motion-picture equipment. Comparisons were based on reactions to the point of major post failure. Major comparisons of 6x6-inch and 6x8-inch red oak and southern pine posts with W6x8.5 and S3x5.7 steel posts showed wooden posts to be equal or superior to steel. The basis for wooden-post specifications should be the amount of knot-associated grain distortion in the middle third of the tension face of the posts. Acceptable posts are those with no single knot in the middle third of the tension face that disorients the grain for more than one-third the width of the face.

*Gibson, Harry G., and Cleveland J. Biller.
1974. **Side-slope stability of logging tractors and forwarders.** Am. Soc. Agric. Eng. Trans. 17(2) : 245-250, illus.

Articulated-frame, four-wheel-drive, rubber-tired logging tractors were analyzed with a mathematical model for determining side-hill stability. A simulation method was used to translate tipping conditions into equations, and a computer program was developed for predicting static tipping angles.

Gibson, Lester P.
1974. **South American *Urosigalphus* (Hymenoptera: Braconidae).** Entomol. Soc. Am. Misc. Publ. 9(4) : 203-226.

This paper includes 23 species (20 new) from South America and 1 species (new) from Trinidad. Three subgenera are represented: *Bruchiurosigalphus* with 4 species, *Urosigalphus* with 5 species, and *Neourosigalphus* with 15 species. The known biology and distribution of each species are given, with complete descriptions. The species are internal parasites of Bruchidae and Curculionidae.

*Gill, John D., Richard M. DeGraaf, and Jack Ward Thomas.
1974. **Forest habitat management for nongame birds in central Appalachia.** USDA For. Serv. Res. Note NE-192. 6 p.

To woodland owners or managers who are interested in bird-habitat improvement, the authors suggest managing for: (1) people with slight to moderate knowledge of birds; (2) high numbers of both individual birds and bird species, particularly the conspicuous species; (3) seeing and hearing birds near trails and other human-activity areas; (4) bird nesting; and (5) natural-appearing habitat. The nesting-habitat preferences of 31 representative species are listed. Guidelines are offered for trails, sites, plants, growth stages, dimensions and lay-out, and treatments.

*Gill, John D., and William M. Healy.
1974. **Shrubs and vines for Northeastern wildlife.** USDA For. Serv. Gen. Tech. Rep. NE-9. 180 p., illus.

A non-technical handbook in which 34 authors discuss management of 97 native and 3 naturalized shrubs or woody vines most important to wildlife in the Northeast—Kentucky to Maryland to Newfoundland to Ontario. Topics include range, habitat, life history, uses, propagation, and management; but not identification. This handbook was produced in cooperation with the Northeastern Deer Study Group and its sponsor, the Association of Northeast Game, Fish, and Conservation Commissioners.

Gill, John D., and William M. Healy.
1974. **A handbook on shrubs and vines.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 1.

Introduction to the handbook, which was prepared to provide practical information about managing the shrubs and woody vines of the Northeast that are important to wild birds and mammals for food and protective cover.

Gill, John D., and Franz L. Pogge.
1974. ***ARONIA* Med.: Chokeberry.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 232-234, illus.

For three species of chokeberry, the authors discuss and describe growth habit, occurrence, use, flowering and fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, germination treatments, germination tests, and nursery practice.

Gill, John D., and Franz L. Pogge.
1974. *CHIONANTHUS VIRGINICUS* **L.: Fringetree.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 323-325, illus.

The authors discuss and describe growth habit, occurrence, use, flowering and fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, germination tests, and nursery practice.

Gill, John D., and Franz L. Pogge.
1974. *PYRUS* **L.: Pear.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 689-691, illus.

For two species of pears, the authors discuss and describe growth habit, occurrence, use, flowering and fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, germination tests, and nursery practice.

Gill, John D., and Franz L. Pogge.
1974. *PHYSOCARPUS* **Maxim.: Ninebark.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 584-586, illus.

For two species of ninebark, the authors discuss and describe growth habit, occurrence, use, flowering and fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, germination tests, and nursery practice.

Gill, John D., and Franz L. Pogge.
1974. *PARTHENOCISSUS* **Planch.: Creeper.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 568-571, illus.

For three species of creepers, the authors discuss and describe growth habit, occurrence, use, flowering and fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, germination tests, and nursery practice.

Gill, John D., and Franz L. Pogge.
1974. *CYTISUS SCOPARIUS* **(L.) Lk.: Scotch broom.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 370-371, illus.

The authors discuss and describe growth habit, occurrence, use, flowering and fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, germination tests, and nursery practice.

Gill, John D., and Franz L. Pogge.
1974. *ROSA* **L.: Rose.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 732-737, illus.

For ten species of roses, the authors discuss and describe growth habit, occurrence, use, flowering and fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, germination tests, and nursery practice.

Gill, John D., and Franz L. Pogge.
1974. *VIBURNUM* **L.: Viburnum.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 844-850, illus.

For ten species of viburnums, the authors discuss and describe growth habit, occurrence, use, flowering and fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, germination tests, and nursery practice.

Gill, John D., and David P. Worley.
1974. **Inventory for managing timber and wildlife habitat.** Timber-Wildl. Manag. Symp. Proc. Univ. Mo. Occas. Pap. 3: 26-32.

Managing timber and wildlife habitat requires inventories to match ownership objectives with land capabilities, selection management alternatives, and evaluate the management. For small privately owned properties, requirements of such inventories are discussed, and a two-stage system is proposed. The first phase screens out unnecessary measurements and saves time and money in the second, more technical phase.

Gove, J.P., and M.C. Hoyle.
1974. **Peroxidase isoenzymes of yellow birch and horseradish.** Am. Soc. Plant Physiol. Annu. Meet. Abstr. 230: 41. Cornell Univ.

The dual catalytic ability of peroxidase isozymes to catalyze oxidation of indoleacetic acid was examined after separation by isoelectric focusing in polyacrylamide gels. All isozymes showed dual catalysis, and highest activity (both types) was found on isozymes with highest isoelectric points.

Gregory, Garold F., and Thomas W. Jones.
1974. **Protection of sand-grown red oak seedlings from oak wilt disease by drenching with benomyl.** USDA Plant Dis. Rep. 58(1) : 65-67.
Treatment of sand-grown red oak seedlings with aqueous suspensions of benomyl resulted in accumulation of fungitoxicant in the stems and leaves and in the prevention of the oak wilt disease.

Grisez, Ted. J.
1974. *PRUNUS* **L.: Cherry, peach, and plum.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 658-673, illus.
New information on species included in the 1948 Woody Plant Seed Manual and several additional species. Seed characteristics, storage, stratification, and germination methods and nursery practices for 24 species are described. Seeds of many species of cherries and plums will germinate well if cleaned promptly after collection, surface-dried only, and sown early in fall or stratified 90 to 150 days before spring sowing.

Hacskaylo, E., and C.M. Tompkins.
1973. **World literature on mycorrhizae.** Reed Herb. Contrib. 22. 142 p.
About 3,000 references to works dealing with mycorrhizae in forestry, legumes, orchids, crops, and ornamentals.

Hamilton, Tom S., Jr.
1974. **Eastern hophornbeam.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 83-85.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Hamilton, Tom S., Jr.
1974. **Sassafras.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 122-125.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

*Hay, C. John.
1974. **Timber beetle defect in black oak in western North Carolina.** South. Lumberman 228 (2826) : 9-10.
A new host, *Quercus velutina,* is specified for the Columbian timber beetle, *Corthylus columbianus.* Factory-grade logs cut from 45 black oak trees on a cove site were examined in a mill study. Beetle defect occurred in lumber from 29 percent of the trees sampled. However, less than 2 percent of the lumber was actually degraded. The loss to this insect was $0.35 per M board feet of lumber sawn. The Damage impact is greatest in the butt and second logs grading as ones or twos.

Hay, C. John.
1974. **Survival and mortality of red oak borer larvae on black, scarlet, and northern red oak in eastern Kentucky.** Entomol. Soc. Am. Ann. 67(6) : 981-986.
Survival and mortality of three generations of the red oak borer, *Enaphalodes rufulus* (Haldeman), were studied over a 7-year period. The borers showed a preference for black oak over red and scarlet oaks. Larval mortality was about the same on all hosts. Tree vigor and size did not affect larval mortality; however, both factors did influence attack density. Larval mortality was 40 percent in the early instars, primarily because of woodpecker predation.

Healy, William M.
1974. **Wild turkey traits.** Turkey Call 2 (1) : 17-24.
A general description of the behavior of human-imprinted wild turkeys from hatching to maturity. The technique of using imprinted birds to evaluate habitat is described, and the relationships between poult behavior and food and cover are discussed.

Healy, William M., and John D. Gill.
1974. **Alders.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 6-9.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Healy, William M., and Sadie L. Robinette.

1974. **Huckleberries.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 89-92.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

*Heisler, Gordon M.

1974. **Trees and human comfort in urban areas.** J. For. 72: 466-469, illus.

The most important contribution of trees to amelioration of urban microclimate is in interception of solar radiation. Shielding of long-wave radiation by trees has usually been underemphasized. Transpiration by trees may be important in urban energy budgets, but the total effect of transpiration by city trees is not well understood. Use of trees for control of air flow requires care because in summer increased wind speed is desired, but in winter trees can greatly increase human comfort by reducing wind speed. Metabolism and photosynthesis by trees have no significant impact on microclimate.

Hejnowicz, Zygmunt.

1974. **Pulsations of domain length as support for the hypothesis of morphogenetic waves in the cambium.** Acta Soc. Bot. Pol. 43: 261-271.

The existence of orientational domains in the cambia of trees is complicated by the slow migration and pulsation of the domain pattern. A unifying hypothesis, invoking morphogenic waves, is offered here: the domain pattern itself represents the spatial aspect of the wave. The reversals of domain type at a particular site represent the time aspect. The pulsations are due to superposition of waves of different length and velocity. The hypothesis can be tested by detailed study of the microanatomy of samples of wood that have wavy or interlocked grain patterns.

Hejnowicz, Z.

1973. **Morphogenetic waves in the cambia of trees.** Plant Sci. Lett. 1: 359-366.

The migrating domain patterns of cambia can be interpreted as morphogenic wave phenomena. The waves are slow, moving only a few millimeters or centimeters per year. The period is about 10 years. Waves of two or more wavelengths can coexist in the same cambium. The interference of such waves produces a stationary pattern of beats. These concepts have been incorporated into a working hypothesis linking morphogenic waves with spatial organization in developing plants.

Hejnowicz, Z., and B. Zagórska-Marek.

1974. **Mechanism of changes in grain inclination in wood produced by storeyed cambium.** Acta Soc. Bot. Pol. 43: 381-398.

Wood having interlocked grain is not limited to species having non-storied cambia and extensive intrusive growth of fusiform elements; it occurs in species with storied cambia also. The question of the cellular mechanism of change in grain orientation in storied cambia was investigated by anatomical study of *Tilia* and *Entandrophragma* wood. Evidentally the very limited intrusive growth of axial elements in storied cambia is adequate to allow the observed changes in cell orientation.

Holweg, Arthur W.

1974. **Common winterberry.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 150-153.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Hornbeck, James W., C. Anthony Federer, and Robert S. Pierce.

1974. **Managing New Hampshire forests for water.** N.H. Water Works Assoc. 35 (4): 7-18.

The relationships between forests and streamflow in New Hampshire are discussed, and some possibilities are given for managing forests to improve and protect water supplies.

*Hornbeck, James W., and Gene E. Likens.

1974. **The ecosystem concept for determining the importance of chemical composition of snow.** Natl. Acad. Sci. Interdisciplinary Symp. on Adv. Concepts and Tech. in Study of Snow and Ice Resour. Proc.: 139-151.

The importance of the snow pack was evaluated in relation to chemical inputs to a forest ecosystem and to chemical outputs in

streamflow. Just before spring melt the snowpack contained about 50 percent of the total calcium and 25 percent of the total nitrate and sulfate input to the ecosystem in winter precipitation. Postassium in the snowpack just before melt was nearly twice the amount of input by winter precipitation. For all four ions the amount stored in the snowpack was small in relation to the amount lost in streamflow.

Hornbeck, James W., and Gene E. Likens.
1974. **Importance of the chemical composition of the snowpack.** East. Snow Conf. Annu. Proc. 31: 145-155. Ottawa.
The chemical composition of the snowpack was determined throughout the winter of 1972-73 in the Hubbard Brook Experimental Forest, New Hampshire. The snowpack was slightly less acid and had about the same or lower concentrations of calcium, nitrate, and sulfate than incident precipitation. The amount of nutrients stored in the snowpack was generally small in relation to the amount lost from the ecosystem in streamflow.

Hosier, Paul E.
1974. **Maples.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 93-95.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Hosier, Paul E.
1974. **Striped maple.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 96-97.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Houston, David R.
1974. **Diebacks and declines: diseases initiated by stress, including defoliation.** Arborists News 49: 73-76. [Reprinted from Int. Shade Tree Conf. Proc. 49: 73-76. 1973.]
The results of recent studies by the author and his colleagues on the physiology and ecology of maple and oak declines, and some implications and potential uses of these results are presented.

Houston, David R.
1974. **Basal canker disease of white pine: ecological comparison between disease development in New York and Maine.** (Abstr.) Phytopathology 64(5): 582.
Basal canker on white pines planted along Route I-95 in central Maine was noted in 1972. Study revealed marked ecological similarities between this situation and that on Tug Hill in north-central New York. In both places, young trees injured by ants, *Formica fusca,* or by snow or ice were invaded by canker fungi; and damage was associated with site features that influenced occurrence of ant mounds or accumulation of ice and snow. Greenhouse inoculation trials confirmed pathogenicity of several fungal isolates, including a *Fusarium* sp.

Hoyle, M.C., E.R. Hager, and J.P. Gove.
1974. **Problems in total extraction of IAA oxidase from birch leaves.** Third North Am. For. Biol. Workshop Proc.: 361 Colo. State Univ.
Complete extraction of soluble IAA oxidase from birch leaves was examined by use of numerous factors. Sulfhydryl reagents, chelators, and dialysis were not effective. Total extraction was achieved with pH 6 buffer, 0.2% detergent (Triton X-100), and 60% phenol scavenger (polyvinylpyrollidone), with optimal extraction times and tissue buffer ratios.

*Huyler, Neil K.
1974. **Live-sawing: a way to increase lumber grade yield and mill profits.** USDA For. Serv. Res. Pap. NE-305. 9 p., illus.
A study to compare live-sawing with conventional grade-sawing of factory-grade 3 red oak sawlogs revealed that live-sawing results in substantial increases in production rate, overrun, log value per thousand board feet, and significant reduction in size of the breakeven log diameter.

Jackson, Lawrence W.
1974. **Honeysuckles.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 71-82.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Jensen, Keith F.

1974. **Absorption, translocation, and soil deposition of aerial pollutants by vegetation.** Soil Conserv. Soc. Am. Annu. Proc. 28: 26-29.

Vegetation reduces atmospheric levels of a wide range of pollutants, including sulfur dioxide, ammonia, fluorides, and many heavy metals. Information on the absorption of pollutants, their translocation through the plant system, and subsequent deposition in the soil is vital to our understanding of air-pollution effects on food chains, plant growth and productivity, and soil toxicity.

*Jensen, Keith F., and Leon S. Dochinger.

1974. **Responses of hybrid poplar cuttings to chronic and acute levels of ozone.** Environ. Pollut. 6: 289-295, illus.

Hybrid poplar cuttings were exposed to either 0-15 ppm ozone for 6 weeks or 1 ppm ozone for 2, 4, or 8 hours. The chronic ozone treatment reduced growth by 50 percent and caused injury to 75 percent of the leaves. The acute ozone treatment had no effect on growth but caused injury to 70 percent of leaves 48 hours after fumigation.

Jensen, K.F., and T.T. Kozlowski.

1974. **Sulfur dioxide absorption and translocation in forest tree seedlings.** (Abstr.) Am. J. Bot. 61(5): 28.

One-year-old seedlings of *Acer saccharum, Populus grandidentata, Fraxinus americana,* and *Betula alleghaniensis* were fumigated with sulfur dioxide ($SO_2$). $SO_2$ absorption rates were measured for seedlings that had been prefumigated with 0.75 ppm $SO_2$ for up to 34 hours. With no prefumigation, *Populus grandidentata* had the highest absorption rate and *Acer saccharum* the lowest. Translocation of absorbed sulfur was measured with $^{35}SO_2$. For the first 4 days after fumigation, most of the radioactive sulfur was found in leaves, but by the eighth day large amounts were also found in the roots.

Jensen, K.F., and T.T. Kozlowski.

1974. **Effect of $SO_2$ on photosynthesis of quaking aspen and white ash seedlings.** (Abstr.) Third North Am. For. Biol. Workshop Proc.: 359.

Rates of photosynthesis of quaking aspen and white ash seedlings were measured before and after fumigation for 2 or 4 hours with 0.2, 0.5, 1.0, or 4.0 ppm $SO^2$. No marked change in rate was recorded after fumigation at 0.2 or 0.5 ppm, but 1 ppm caused a slight reduction in photosynthesis and 4 ppm caused a large decrease. Within 24 hours photosynthesis of all seedlings had partially or completely recovered.

*Johnson, Leonard R., Cleveland J. Biller.

1974. **Wood-chipping and a balanced logging system simulation can check the combinations.** Am. Soc. Agric. Engin. Trans. 17(4): 651-655, illus.

The best cost picture will result when the production capabilities of fellers, skidders, and trucks working with a chipper are matched with the chipper's capability. SAPLOS (Simulation APplied to LOgging Systems), a simulation model, was used to test various combinations of men and equipment for a logging site.

*Keiser, George M.

1974. **A guide to collecting and preserving plants.** USDA For. Serv. Res. Note NE-188. 6 p., illus.

Directions for collecting and preserving plant specimens. Plant pressing, mounting, and labeling techniques are described.

Kennedy, Bruce H.

1974. **Net reproduction of *Dendrosoter protuberans* (Nees), *Spathius benefactor* Matthews and *Cheiropachus colon* (L.) reared on larvae of *Scolytus multistriatus* (Marsham).** Entomol. Soc. Am. North Cent. Branch Annu. Meet. 29: 178-179. Des Moines, Iowa.

Studies were conducted to determine the net reproduction of *Dendrosoter protuberans* (Nees), a braconid recently introduced from France; *Spathius benefactor* Matthews, a native braconid; and *Cheiropachus colon* (L.), a pteromalid—all of which can parasitize late-instar larvae of *Scolytus multistriatus* (Marsham). Under laboratory conditions, *D. protuberans* averaged 11 progeny per pair, and *S. benefactor* averaged 6 per pair. Under field conditions, *D. protuberans* averaged 10 per pair and *S. benefactor* averaged 6. *C. colon* produced an average of 27 progeny per pair.

Kennedy, Bruce H., and Nick H. Roberto.

1974. *Dendrosoter protuberans* **(Nees) an introduced parasite of** *Scolytus multistriatus* **(Marsham) is established in Detroit, Michigan.** Entomol. Soc. Am. North Cent. Branch Annu. Meet. 29: 177-178. Des Moines, Iowa.

*Dendrosoter protuberans* (Nees), a braconid introduced from France, and a parasite of *Scolytus multistriatus* (Marsham), has become established in Detroit, Michigan. Releases were made in 1968 at River Rouge Park and in the suburbs of Bloomfield Hills and Warren, Michigan, in 1969. Individuals were recovered from beetle-infested elm wood taken from River Rouge Park in the winter and summer of 1972 and from wire mesh traps attached to beetle-infested trees in River Rouge Park in the summer of 1972. In 1973, *D. protuberans* was collected from beetle-infested elms in other areas of Detroit and suburbs.

*Kingsley, Neal P.

1974. **The timber resources of Southern New England.** USDA For. Serv. Resour. Bull. NE-36. 50 p., illus.

A statistical and analytical report on the second forest survey of Connecticut, Rhode Island, and Massachusetts. Statistical findings are based on the remeasurement of 1/5-acre plots and new 10-point cluster plots. Trends in forest-land area, timber volume, annual growth, and timber removals are analyzed. Timber-products output by forest industries, based upon a canvass of industries in 1971, and the importance of timber and forests to the region's economy and environment, are also discussed. The report includes a discussion of the outlook for timber supplies during the next 30 years and forest-management opportunities in the region.

Konar, R.N.

1974. **In vitro studies on** *Pinus*. **I. Establishment and growth of callus.** Physiol. Plant. 32: 193-197.

Tissue from *Pinus gerardiana* hypocotyls was established in sterile culture. The nutrient medium was supplemented with sucrose, coconut milk, casein hydrolysate, and 2,4-D. Glutamine could be substituted for casein hydrolysate. Work is in progress toward inducing differentiation of root and shoot meristems in the callus. The ultimate goal is to reproduce large numbers of plantlets from cultured cells or tissues of desirable clones.

Kopcewicz, J., and Z. Porazinski.

1973. **Influence of low temperature on germination and endogenous growth regulator contents in Scots Pine (***Pinus silvestris* **L.) seeds.** Acta Soc. Bot. Pol. 42: 233-240.

After 20 days of cold stratification, Scotch pine seeds germinate equally well in light or darkness. The light requirement is overcome because there is an increase in gibberellin content of the seeds during stratification. New groups of gibberellins become detectable. Seedlings grown from stratified pine seeds also contain increased amounts of gibberellins.

Krawczyszyn, J.

1973. **Domain pattern in the cambium of young** *Platanus* **stems.** Acta Soc. Bot. Pol. 42: 637-648.

During the first year of growth of *Platanus* stems the cambium can already be delineated into domains on the basis of local prevalences of right or left orientations of certain cell divisions. The pattern that appears when these domains are mapped is related to the position of nodes and leaves. As the cambium forms additional annual rings, the domain pattern changes and is probably highly significant in establishing the interlocked grain pattern characteristic of *Platanus* wood.

Kriesel, K., and M. Michniewicz.

1974. **The mutual influence of roots and shoots on gibberellin production.** Bull. Acad. Pol. Sci. Ser. Biol. 22: 507-512.

The type and amount of free and bound gibberellins in shoots and adventitious roots of willow was studied. The data were interpreted as follows: shoots influence the type and amount of gibberellins formed in roots, and vice versa. These results support earlier statements suggesting that both shoots and adventitious roots of willow are sites of gibberellin biosynthesis.

Krochmal, Arnold.

1974. **Some common diseases of papaya.** *CEIBA* 18(1-2): 19-31, illus. (Escuela Agricola Panamericana, Tegucigalpa.)

Papaya, which is gaining importance as a crop because of its excellent flavor and high vitamin-C content, is affected by three fungus diseases (anthracnose, St. Croix decline, and phytophthora) and two virus diseases (mosaic and bunchy top). The symptoms and effects of these diseases are described.

*Krochmal, Arnold, Leon Wilkins, David Van Lear, and Millie Chien.

1974. **Mayapple.** USDA For. Serv. Res. Pap. NE-296. 8 p., illus.

The mayapple (*Podophyllum peltatum* L.), long used in folk medicine, was studied to gain more information about its characteristics and potentialities. The plant and its distribution, site soils, and botany are described. Efforts to germinate seed were unsuccessful. Some notes on chemical properties and biological action.

Krugman, S.L., W.I. Stein, and D.M. Schmitt.

1974. **Seed biology.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 5-40.

The introductory chapter to this seed manual. Seed is the principal means for perpetuation of most trees and many other woody species from one generation to the next. The life of a seed is a complex series of biological events beginning with the flower and ending with germination of the mature seed.

Lancaster, Kenneth F., and Russell S. Walters.

1974. **How to hang plastic tubing to collect maple sap.** USDA For. Serv. Northeast. Area State & Priv. For. 6 p., illus.

A brochure folder showing how to install a plastic tubing system for collecting maple sap. Common errors to avoid are illustrated, including crimping or kinking of lines, leaks at junction points, and sagging lines.

*Lancaster, Kenneth F., Russell S. Walters, Frederick M. Laing, and Raymond T. Foulds.

1974. **A silvicultural guide for developing a sugarbush.** USDA For. Serv. Res. Pap. NE-286. 11 p., illus.

Guidelines for the manipulation of stand density and stocking to promote development of healthy, vigorous trees with deep, wide crowns, the necessary attributes for highest possible yield of sugar-rich sap. Specific treatments are prescribed for sapling, pole-timber, and small sawtimber stands, and a method of selection for thinning is described.

LaPage, Wilbur F.

1974. **Market research—the missing link in resource-development planning for outdoor recreation.** *In* Outdoor recreation research: applying the results. USDA For. Serv. Gen. Tech. Rep. NC-9: 107-113.

The development of progressive models of outdoor recreation markets is described, with emphasis on research findings from the family camping market. An introductory stages-of-growth model is presented in stages: infancy, adolescence, young adulthood, and maturity. From this, a more complete model of camping-market expansion is developed, which details the sizes of and relationships among various segments of the camping market.

*LaPage, W. F., and A. C. Haaland.

1974. **Annotated bibliography of camping market surveys.** USDA For. Serv. Gen. Tech. Rep. NE-11. 39 p.

A compendium of more than 200 published and unpublished surveys and observational studies of campers conducted between 1936 and 1973. The majority of citations are American and Canadian. The bibliography is organized in five categories: national, regional, local, readership, and miscellaneous.

*LaPage, W.F., and D.P. Ragain.

1974. **Family camping trends—an eight-year panel study.** J. Leisure Res. 6: 101-112.

Eight years of annual camping-participation data, reported by a panel of 459 camping families, revealed that 51 percent of the campers were either camping less or had dropped out of camping. One out of every four families had increased its camping participation from an average of 22 days per year in 1964-68 to 36 days in 1969-71. Campers with increasing or decreasing trends were more likely to have experienced a

change in their style of camping than were those families with a constant or highly variable pattern of participation.

*Large, Hollis R., and Richard E. Frost.
1974. **Quality distribution of pallet parts from low-grade lumber.** USDA For. Serv. Res. Pap. NE-284. 8 p., illus.

To produce better pallets, the higher quality parts should be used in the more vulnerable positions in the pallet. To determine the feasibility of doing this, pallet parts cut from commonly used lumber mixes were graded into four quality levels. The distributions obtained indicate that sufficient numbers of high-quality parts can be cut from existing raw material to allow selective placement. Four species groups—eastern hardwood, southern pine, Douglas-fir, and a small amount of western hardwood—were included in the study.

Larson, Joseph S.
1974. **Serviceberries.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 126-128.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Leaf, Albert L., and R.E. Leonard.
1974. **Fertilization in an environmental context.** South. Lumberman 229(2848): 88.

Forest fertilization triggers a host of complex interrelated events within the ecosystem. These events pose (1) potential pollution hazards and (2) potential ecological side effects, including the effects of the initial energy changes on the ecosystem, secondary changes resulting from the initial changes, and societal effects resulting from ecosystem changes. Large-scale fertilization operations may also have an effect on socioeconomic conditions in a region.

Leak, William B.
1974. **Elevation v. tree development.** N.H. For. Notes 119: 24-25, illus.

The relationship of tree development to elevation is basic to the elevational zoning of forest land for a variety of possible uses. Data from a transect on Mt. Whiteface in New Hampshire, coupled with comparative information from other New England sources, indicates that tree/forest development begins to decline appreciably at about ¾ the distance up the mountain range or between 3,000 and 3,300 feet elevation, whichever criterion comes first.

Leak, W.B.
1974. **Review of Systems analysis and simulation in ecology.** Ecology 55(3): 678-679.

A descriptive review of the second volume of "Systems analysis and simulation in ecology," edited by B. Patten.

*Leak, William B.
1974. **Some effects of forest preservation.** USDA For. Serv. Res. Note NE-186. 4 p., illus.

Long-term preservation (no cutting) of a deciduous forest stand in New Hampshire is leading toward stable populations of beech, sugar maple, striped maple, mountain maple, and hobblebush, coupled with a decline or complete disappearance of other woody species. The humus has stabilized at a depth no greater than that of cut stands. Nitrate discharge in the streams is higher than what is normally found in uncut stands, possibly because of stability in standing crop and humus.

Leak, W.B., and R.E. Graber.
1974. **A method for detecting migration of forest vegetation.** Ecology 55: 1425-1427, illus.

A theoretical method is described for detecting and estimating the rate of tree- and shrub-species migration based upon measurements of maximum and minimum age along a transect. Age data from Mt. Washington indicate that the method does detect migrational trends under field conditions, although appreciable variation is encountered.

*Leak, William B., and Raymond E. Graber.
1974. **Forest vegetation related to elevation in the White Mountains of New Hampshire.** USDA For. Serv. Res. Pap. NE-299. 7 p., illus.

Maximum tree size and species composition are related to elevation on Mount Washington (disturbed by logging) and Mount Whiteface (uncut) in the White Mountains of New Hampshire. Species migration trends and differences between the two mountains

in species elevation limits indicate that both hardwoods and softwoods will move to higher elevations in areas where cutting and heavy disturbance are eliminated.

Lesser, Walter A., and Jean D. Wistendahl.
1974. **Dogwoods.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 32-41.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

*Lewis, F.B., N.R. Dubois, D. Grimble, W. Metterhouse, and J. Quimby.
1974. **Gypsy moth: efficacy of aerially-applied *Bacillus thuringiensis*.** J. Econ. Entomol. 351-354.
Eight billion International Units of Dipel® and Thuricide® were applied aerially in New Jersey, New York, and Pennsylvania against *Porthetria dispar* (L). Two gallons of finished spray per acre were applied twice about 10 days apart. Foliage protection was achieved in most cases, but desired population reduction was not achieved. Very rainy cool weather contributed heavily to the results of this experiment.

Liscinsky, Stephen A.
1974. **Gray dogwood.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 42-43.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

*Little, Silas.
1974. **Wildflowers of the pine barrens and their niche requirements.** N. J. Outdoors 1 (3): 17-18, illus.
The New Jersey pine barrens have long attracted botanists and other people interested in rare plants. Many of these plants have niches determined by soil, moisture, amount of overhead light, and sometimes type of forest floor. Certain kinds of disturbances—as fire, timber cutting, mining, construction, and abandonment of logging roads—are needed to provide the conditions these plants require.

Little, Silas.
1974. **Effects of fire on temperate forests: northeastern United States.** *In* Fires and ecosystems: 225-250, illus. Academic Press, New York.
The frequency and type of presettlement fires and postsettlement fires have had major effects on the composition of vegetation in the Northeast. Varying fire history can cause great changes in the forest composition on specific sites, and different species are adapted to different fire regimes. Fire effects are described by types: spruce-fir, northern hardwoods, eastern white pine, oaks, yellow-poplar and sweetgum, pitch pine, Atlantic white-cedar, Virginia pine, and loblolly and pond pines.

Little, Silas.
1974. ***AILANTHUS ALTISSIMA* (Mill.) Swingle: Ailanthus.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 201-202, illus.
Flowering, fruiting, collection of fruits, extraction and storage of seeds, pregermination treatments, and procedures in germination tests and in the nursery are briefly described.

Little, Silas.
1974. **Review of Vegetation of New Jersey.** Torrey Bot. Club Bull. 101(1): 36.
This book is a valuable guide to all persons interested in the broad vegetational types of New Jersey and the factors causing the different types. The book is weakened by its broad-brush treatment of most topics, incomplete literature citations, a few factual errors, and—in the reviewer's opinion—misinterpretation of some successional relationships.

*Little, Silas, Calvin F. Bey, and Daniel McConaughy.
1974. **Local sources of black walnut recommended for planting in Maryland.** USDA For. Serv. Res. Note NE-185. 3 p.
After 5 years, local black walnut seedlings in a Maryland planting were taller than those of 12 out-of-state sources. Seedlings from south-of-local sources outgrew trees from northern sources. Genetic influence on height was expressed early — with little change in ranking of sources after the third year.

MacConnell, William P., and Marcia Cobb.

1974. **Remote sensing 20 years of change in Middlesex County, Massachusetts, 1951-1971.** Mass. Agric. Exp. Stn. Res. Bull. 622. 159 p.

A report on changes in land-use and vegetative types based on interpretation of 1951 and 1971 aerial photographs. Land was classified to a 5-acre minimum in one of six broad types: (1) agricultural or open land, (2) forest land, (3) fresh and salt water wetlands, (4) mining and waste-disposal areas, (5) urban lands, and (6) outdoor recreation facilities. Classification was further subdivided into 104 types. Maps may be ordered to accompany the report.

MacConnell, William P., W. Cunningham, and R. Blanchard.

1974. **Remote sensing 20 years of change in Essex County, Massachusetts, 1951-1971.** Univ. Mass. Coop. Ext. Serv. Publ. 98. 104 p.

See above.

MacConnell, William P., and William Niedzwiedz.

1974. **Remote sensing 20 years of change in Worcester County, Massachusetts, 1951-1971.** Mass. Agric. Exp. Stn. Res. Bull. 625. 173 p.

See above.

MacConnell, William P., H. Ross Pywell, and Peter E. Young.

1974. **Remote sensing 20 years of change in Suffolk and Norfolk Counties, Massachusetts, 1951-1971.** Mass. Agric. Exp. Stn. Res. Bull. 624. 112 p.

See above.

MacConnell, William P., Nancy Arny Pywell, Dana Robertson, and William Niedzwiedz.

1974. **Remote sensing 20 years of change in Barnstable, Dukes, and Nantucket Counties, Massachusetts, 1951-1971.** Mass. Agric. Exp. Stn. Res. Bull. 623. 112 p.

See above.

McGinnes, E.A., Jr., J.E. Phelps, and J.C. Ward.

1974. **Ultra-structure observations of tangential shake formations in hardwoods.** Wood Sci. 6(3): 206-211.

Tangential shake formation in a tree is a highly complex process. In this study a scanning electron microscope and transmission electron microscope were used to explore the wood structure and abnormalities associated with the shake zones in several hardwoods. Results of previous studies were verified, and the desirability of more work on lignin properties and bacteria associations in the shake zones was emphasized.

McGinnes, E.A., Jr., and A.L. Shigo.

1974. **An aid for detection of discoloration and decay in standing trees.** (Abstr.) For. Prod. Res. Soc. 28th. Annu. Meet. Abstr.: 4.

A new approach to the detection of decay or discoloration in its initial stages in standing trees uses an electric current to measure the mobile ion concentration profile within the tree. After a small hole 8-10 inches deep is drilled into the tree, a wire probe is inserted and a pulsed electric current is passed through the wood tissue surrounding the tip of the probe. The changing pattern of resistance readings made at selected intervals from bark to tree interior indicates areas of sound wood, initiation of decay or discoloration, or decayed wood.

*Marquis, David A.

1974. **The impact of deer browsing on Allegheny hardwood regeneration.** USDA For. Serv. Res. Pap. NE-308. 8 p., illus.

To evaluate the impact of deer browsing on Allegheny hardwood regeneration, surveys of vegetation were made inside and outside deer exclosures in 13 stands that had been clearcut 5 to 16 years earlier. The surveys showed that browsing by white-tailed deer has resulted in regeneration failures in 25 to 40 percent of the areas studied. Pin cherry and sugar maple were the species most severely reduced by browsing, while beech, birch, and striped maple increased in proportion to other species in areas subjected to deer.

Martell, Arthur M.

1974. **Canada yew.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 158-160.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Michalski, Leszek.

1974. **Content of plant growth regulators in the developing seeds of oak (*Quercus robur* L.). III. Kinetin-like substances.** Acta Soc. Bot. Pol. 43: 307-312.

Changes in the complement of kinetin-like substances in developing acorns were studied. Active cell-division-promoting substances can be detected at various stages of seed development. In the course of seed maturation there is a decline in the content of activity of such substances.

Michniewicz, M., and E. Galoch.

1974. **The role of vanillin and p-coumaric acid in the growth of Scotch pine seedlings.** Acta Soc. Bot. Pol. 43: 273-281.

Low concentrations of vanillin and p-coumaric acid stimulate the growth of pine seedlings. The most effective concentration is $10^{-7}$ M. In young seedlings there is an effect upon both elongation and fresh and dry weight; later only a weight effect is evident. Growth stimulation in treated plants was accompanied by an increase in auxin and a decrease in free gibberellins. No effects upon abscisin-like inhibitors could be detected.

Michniewicz, M., E. Galoch, B. Rozej, and Z. Zatorska.

1974. **Dynamics of endogenous plant growth regulators in the early stages of growth and development of Scotch pine seedlings (*Pinus silvestris* L.).** Bull. Acad. Pol. Sci. Ser. Biol. 22: 625-631.

The growth rate of pine seedlings is typically high during the first 7-8 days after germination. This intensive growth is correlated with high levels of free gibberellins and low levels of abscisin-like inhibitors. Decreasing growth after 10 days is correlated with increasing inhibitor content. No correlation could be established between activity of auxins and cytokinins in the shoots and the rate of growth. The rate of leaf primordium initiation is correlated with auxin level in the roots.

Moeller, G.H., and H.E. Echelberger.

1974. **Approaches to forecasting recreation consumption.** *In* Outdoor recreation research: applying the results. [Marquette, Mich., Workshop Proc.] USDA For. Serv. Gen. Tech. Rep. NC-9: 43-55.

Approaches to forecasting consumption of resource-based outdoor recreation are summarized. Although the discussion is oriented toward the quantity of recreation that will be consumed, qualitative aspects of recreation experiences and environments are also discussed. Forecasting models are evaluated in terms of suitability for recreation planning and accuracy of results.

*Moeller, G.H., and J.H. Engelken.

1974. **What fishermen look for in a fishing experience.** Trout 5(4): 28, 43-44. [Reprinted from J. Wildl. Manage. 36: 1254-1257, 1972.]

One hundred fishermen in central New York State were interviewed to determine the relative importance of eight selected factors that influence the success of a typical 1-day fishing trip. Elements of the natural environment—water quality, natural beauty, and privacy—were consistently rated as most important. Size and number of fish caught, weather conditions, and access to fishing waters were rated moderate. Facilities available were given low ratings.

*Moeller, George H., Rodney G. Larson, Douglas A. Morrison.

1974. **Opinions of campers and boaters at the Allegheny reservoir.** USDA For. Serv. Res. Pap. NE-307. 26 p., illus.

Interviews with 157 campers and 281 boaters near the Allegheny Reservoir on the Allegheny National Forest revealed that their perceptions of management problems differed from those of managers. Different users had different attitudes toward recreation use controls, fee policies, recreation zoning, law enforcement, and facility development needs. This diversity indicates that changes in recreation management policy will not affect all recreation users equally; their impact will depend on how active the users are, the number of activities they participate in, and how familiar they are with the area.

*Moeller, George H., Robert MacLachlan, and Douglass A. Morrison.

1974. **Measuring perception of elements in outdoor environments.** USDA For. Serv. Res. Pap. NE-289. 9 p., illus.

The meanings of 10 general concepts that describe elements of natural outdoor environments and experiences were measured with the semantic differential technique. Each element or concept was evaluated in terms of semantic scores on three factors of meaning—evaluation, potency, and activity. A total of 180 recreationists were surveyed —60 from each of three recreation groups. Similarities and differences were found among the three groups—campers, picnickers, and wilderness hikers—in the ways in which they perceived each other and elements of recreation environments. Although they are tentative, study results should contribute toward a better understanding of the way in which people relate to outdoor environments and what they expect from those environments.

*Nevel, Robert L., Jr.
1974. **Use of hardwood flooring in urban rehabilitation.** For. Prod. J. 25(1): 13-16.
Although one of the major wood products used in urban rehabilitation is hardwood flooring, the use of hardwood flooring in new or renovated housing is decreasing relative to other flooring materials. The most important factors limiting use of hardwood flooring are related to product availability, cost to the building contractor, efficiency of installation, and compatibility with construction practices. To lessen the effect of these factors, the author recommends a well-rounded marketing and distribution program and basic changes in product design and installation techniques.

*Nevel, Robert L., Jr.
1974. **Recommended action for the wood-flooring industry to secure its share of the urban rehabilitation market.** USDA For. Serv. Res. Pap. NE-287. 5 p.
Urban rehabilitation is a major market for wood flooring, but wood flooring must be made more acceptable to the building contractor and housing owner. Changes in distribution, supply, and pricing could make wood flooring more readily available; product modification could reduce its short-term costs; and other changes could make wood flooring more economical and compatible with present working methods.

Nixon, Charles M., and D. Michael Worley.
1974. **Partridgeberry.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 111-112.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Northeastern Forest Experiment Station.
1974. **1973 at the Northeastern Station.** USDA For. Serv. Northeast. For. Exp. Stn., Upper Darby, Pa. 59 p., illus.
A summary of research activities and accomplishments in timber management, forest insects and diseases, forest economics, watershed management, forest products utilization, forest survey, forest recreation, environmental forestry research, wildlife habitat, forest engineering, and forest products marketing. Annotated list of publications.

*Northeastern Forest Experiment Station.
1974. **Forestry Sciences Laboratory, Warren, Pennsylvania.** USDA For. Serv. Northeast. For. Exp. Stn. 4 p. plus inserts.
A pocket brochure describing research at the Station's laboratory at Warren, Pa. Inserted folders contain details about the laboratory and its facilities, and about the research programs in timber management and wildlife-habitat management.

*Northeastern Forest Experiment Station.
1974. **To heal the scars.** USDA For. Serv. Northeast. For. Exp. Stn. 16 p., illus.
A two-color brochure on strip-mine reclamation research at Berea, Ky., describing the processes and problems associated with surface mining in the Appalachians and the tools and methods that researchers use to reclaim damaged land.

*Northeastern Forest Experiment Station.
1974. **Northeastern Forest Experiment Station.** USDA For. Serv. Northeast. For. Exp. Stn. 12 p., illus.
A booklet describing research at the Northeastern Station. The laboratories are listed alphabetically and short summaries are given of the work of each research unit. A map of the Station is included.

*Northeastern Forest Experiment Station.
1974. **Leisure environments—now, 2000 and beyond.** USDA For. Serv. Northeast. For. Exp. Stn. 8 p., illus.

A look into the future of natural resource and use and management, predicting how we might work and play by the year 2050 and what policies and regulations we can expect. This brochure contains futuristic drawings that illustrate predictions by experts in environmental fields.

*Northeastern Forest Experiment Station.
1974. **Trees are . . . [environmental wonder workers].** USDA For. Serv. Northeast. For. Exp. Stn. 6 p.

A meteorological view of trees. This fold-out brochure tells how trees interact with the forces of nature—sun, wind, and rain—to modify earth's climate.

*ODell, T. M., P. A. Godwin, and W. B. White.
1974. **Radiographing puparia of tachinid parasites of the gypsy moth, and application in parasite-release programs.** USDA For. Serv. Res. Note NE-194. 4 p., illus.

A radiographic technique has been developed for observing and quantifying development and mortality of *Blepharipa scutellata* (Robineau-Desvoidy), *Parasetigena agilis* (Robineau-Desvoidy), and *Compsilura concinnata* (Meigen), tachinid parasites of the gypsy moth, *Porthetria dispar* (L.). Puparia can be examined and sorted immediately after collection, and decisions on further collecting and release can be made in the fall. Healthy tachinid pupae can be placed directly in a release area, eliminating the handling of adults the following spring.

Olson, David F., Jr., and W.J. Gabriel.
1974. *ACER* **L.: Maple.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 187-194, illus.

A description of this important genus, including growth habit, occurrence and use; flowering and fruiting; collection of fruits; extraction and storage of seeds; pregermination treatments and germination tests; and nursery practice.

Ostrander, M.D.
1974. **Eastern spruce . . . an American wood.** USDA For. Serv. Am. Woods Ser. FS-263. 10 p., illus.

Three spruce species—white, black, and red—grow in much of Canada and in the northeastern United States and are called collectively Eastern Spruce. The wood is moderately soft, medium to fine textured, and usually straight-grained; it is used for pulp, prefabricated dwellings, mobile homes, furniture, and construction. Spruce lumber has moderately high shrinkage, but it is easily dried and worked; it is low in nail-holding ability and resistance to decay.

*Parker, Johnson.
1974. **Seasonal changes in phenol-bound sugars in bark of some deciduous forest trees.** Can. J. For. Res. 4(3) : 291-295.

The prominent phenol-bound sugars in bark of the five tree species studied declined from winter to summer on a fresh, but not on a dry-weight basis. Rhamnose was the phenol-bound sugar occurring in greatest quantity in *Quercus velutina* and *Carya glabra,* xylose in *Betula lenta,* and glucose in *Fraxinus americana* and *Acer saccharum.* Glucose was a common phenol-bound constituent of all these species. Rhamnose, bound to phenols in *Quercus velutina,* made up as much as 2.5 percent of fresh weight in winter. Galactose and fructose, found in hydrolyzed ethanol-water extracts, originated largely from oligosaccharides.

*Parker, Johnson.
1974. **Effects of defoliation, girdling, and severing of sugar maple trees on root starch and sugar levels.** USDA For. Serv. Res. Pap. NE-306. 4 p.

Root starch levels of defoliated sugar maple trees, on the average, were lower after 4 weeks in two separate experiments than in girdled, cut off, or girdled and defoliated trees. Root starch levels in all these treatments were lower than in controls. Sucrose levels—but not the levels of fructose and glucose—followed the same trends. It is suggested that carbohydrates are moved upward in the phloem of the stem and to a lesser extent in the xylem in defoliated trees, and that this accounts for the relatively low levels of starch and sucrose in these trees' roots.

Parker, Johnson.
1974. **Seasonal changes in some bark pigments in** *Quercus velutina.* (Abstr.) Plant Physiol. Suppl. vol. 54 (June 1974) : 33.

Chloroplast pigments, including mostly chlorophylls, xanthophylls, and carotene, decreased in early summer and rose again in early winter. Phenolics, including tannins, changed very little over the same period. Most of the seasonal change in phenolics, when based on fresh weight, could be explained by changes in bark water content. Bark water content in winter was nearly half that in summer.

*Patric, James H.

1974. **River flow increases in central New England after the hurricane of 1938.** J. For. 72: 21-25, illus.

The New England hurricane of 1938 uprooted or broke off vast numbers of trees in watersheds of the Connecticut and Merrimack Rivers. Annual flow in both rivers increased about 5 inches during the first year after the hurricane. Another 5 inches of increased flow ran off at diminishing rates during the next 2 or 3 years. At least half of these flow increases occurred in July, August, and September, when streams normally are at the lowest levels of the year. There was no evidence of increased flow 5 years after the hurricane, when forest regrowth was well under way.

Patric, James H.

1974. **Water relations of some lysimeter-grown wildland plants in southern California.** 130 p., illus. USDA For. Serv. Northeast. For. Exp. Stn., Upper Darby, Pa.

An office report on lysimeter installations operated from 1937 until 1960 near Los Angeles. Diminished growth by lysimeter plants and disproportionately large surface runoff suggest that the lysimeter results can be applied to forested watersheds only with greatest caution. Later research methods provide more reliable knowledge of plant-water relationships at considerably less cost.

Patric, James H.

1974. **Soil water relationships in uncut and cut forests.** *In* Notebook for Logging Road and Skid Trail Workshops. W. Va. Univ. Coop. Ext. Serv. 9 p.

Logging roads and skid trails are by far the greatest sources of eroding soil and sediment from the eastern hardwood forest. This brief paper contrasts some soil-water relations before and after timber harvest. It was the basis of oral presentations on forest hydrology at a series of workshops on logging roads, providing take-off points for following speakers concerned with soils, engineering, and management of logging roads.

Payne, Brian R., and Jack W. Thomas.

1974. **Multiple Use: Who is the public and what are they saying?** Timber-Wildl. Manage. Symp. Proc.: 108-111. Mo. Acad. Sci. Occas. Pap. 3, Columbia, Mo.

Land managers have a professional responsibility to involve the public in multiple-use decisions. The public is increasingly urban, affluent, and educated, more concerned with wildlife than timber, and increasingly concerned with non-game and endangered species. Research is needed to identify the public and their changing needs.

Pearce, G.T., W.E. Gore, R.M. Silverstein, G.N. Lanier, J.B. Simeone, J.W. Peacock, R. Cuthbert.

1974. **Aggregation pheromone of the smaller European elm bark beetle,** ***Scolytus multistriatus.*** Int. Union Pure and Appl. Chem. Int. Symp. Chem. Nat. Prod. 9: 1E. Ottawa, Canada.

The pheromone of *Scolytus multistriatus* must be isolated, identified, and artificially synthesized before the attractant can be evaluated as a tool for control of this insect. The attractant blend has been isolated and the individual components identified as: (1) (—) 4-methyl-3-heptanol; (2) 2,4-dimethyl-5-ethyl-6, 8-dioxabicyclo (3.21) octane (multistriatin); and (3) (—) α-cubebene. Preliminary field studies indicate this mixture is attractive to beetles in flight. The synthetic attractant blend can now be evaluated in large-scale field tests to manipulate beetle populations and as a tool for beetle detection and survey.

Plass, William T.

1974. **Revegetation projects dominate surface-mine research.** Coal Min. & Process. 11(8): 40-42.

A review of the research accomplishments of the Forest Service and other research groups in West Virginia. Revegetation, which domi-

nated efforts in the past, will become less important. The development of practical land-management methods could dominate future research as more emphasis is placed on returning surface-mined lands to productive use.

*Plass, William T.

1974. **Factors affecting the establishment of direct-seeded pine on surface-mine spoils.** USDA For. Serv. Res. Pap. NE-290. 5 p., illus.

In a greenhouse study the emergence, survival, and growth of seven species of pine were related to chemical and textural characteristics of 12 Kentucky spoils. The results identify three factors that may affect the establishment of direct-seeded pine on surface-mine spoils. First, fine-textured spoil material may restrict seedling emergence. Second, species vary in their response to chemical and physical characteristics of the spoil material. Finally, the growth of loblolly pine was greater where the percentage of phosphorus in the whole plant was greatest.

Plass, William T.

1973. **Chemical soil stabilizers for surface mine reclamation.** *In* Soil erosion: causes and mechanisms; prevention and control. Highw. Res. Board Spec. Rep. 135: 118-122. (Workshop Conf. Proc.) Washington.

Two cooperative demonstrations compared vegetation establishment and erosion loss following 30 treatments with 6 mulches and 12 soil stabilizers. There is no evidence that these materials are necessary for vegetation establishment; they are used primarily to control erosion. Mulches, soil stabilizers, and soil stabilizer-mulch combinations were all found to be effective for this purpose.

*Plass, William T., and John P. Capp.

1974. **Physical and chemical characteristics of surface mine spoil treated with fly ash.** J. Soil and Water Conserv. 29(3): 119-121, illus.

The use of power-plant fly ash for surface-mine reclamation offers an attractive outlet for the millions of tons that are produced annually. Research by the U.S. Bureau of Mines indicates that large quantities of alkaline fly ash may lower bulk density, increase pore space, increase available water, add several plant nutrients, and neutralize acidity. In this study, the application of 150 tons of alkaline fly ash per acre significantly increased pH and soil phosphorous. Physical characteristics were also changed by the fly ash treatment. Spoil density was reduced and more soil moisture accumulated at lower depths. This indicates that the fly ash treatment increased infiltration rates, increased soil porosity, and increased percolation to a depth of 4 feet.

*Podgwaite, J.D., R.D. Neely, and R.T. Zerillo.

1974. **Reusable, autoclavable silicone rubber dish for insect dissection.** J. Econ. Entomol. 67(3): 458-459, illus.

A dissecting dish possessing the positive attributes of conventional wax and paraffin dishes was prepared, using a silicone encapsulant. Because the silicone remains rubbery from —65° to 250°C, the dish can be used for pathological studies, autoclaved, and reused many times. In addition, dissecting pins are held more firmly than in wax or paraffin and the silicone reseals when cut with a sharp instrument or when pins are removed. Although specifically designed for the dissection of insects, the dish could be adapted for use with other biological specimens.

*Pogge, Franz L., John D. Gill, and Bradford C. Bearce.

1974. **Rooting common and cat greenbrier.** USDA For. Serv. Res. Note NE-189. 6 p.

Because reliable methods for propagating greenbriers are needed for wildlife-habitat purposes, stem and rhizome cuttings of common and cat greenbrier and tubers of the latter species were tested. Common greenbrier is the better species for most wildlife-habitat uses. It proved fairly easy to propagate from either stem or rhizome cuttings. Similar cuttings from cat greenbrier failed, but tubers rooted well and can be collected at moderate cost. Kinds of cuttings to collect, when to collect them, nursery procedures, and relative costs are discussed.

Pogge, Franz L., John D. Gill, and Bradford C. Bearce.

1974. **Gibberellic acid inhibits greenbrier growth.** Tree Planters' Notes 25(2): 10.

Seeds of common and cat greenbrier (*Smilax rotundifolia* L. and *S. glauca* Walt.) moistened with distilled water germinated better than those moistened with 1, 50, or 100 ppm solutions of $GA_3$. Best germinations were 96 percent for common greenbrier after 9 months and 82 percent for cat greenbrier after 24 months.

Pottle, H.W., and A.L. Shigo.

1974. **Treatment of wounds on *Acer rubrum* with Trichoderma viride.** (Abstr.) Plants and Gard. 29(4) : 14-15.

Wounds on 90 *Acer rubrum* trees were inoculated with *Trichoderma viride* to determine the effects of the fungus on the development of decay. After a year 28 trees were harvested and 12 isolation chips were taken from the discolored or discolored and decayed wood associated with each wound. *Trichoderma viride* was reisolated from all wounds inoculated with it. No decay was associated with wounds inoculated with *T. viride* and no Hymenomycetes were isolated from the discolored wood associated with these wounds.

*Rast, Everette D.

1974. **Nonproductive time in hardwood mills.** South. Lumberman 229 (2843) : 13-15, illus.

Data on 6,083 logs sawed at 21 mills showed a total mill time of 363.9 hours and a total nonproductive time of 39.8 hours. The nonproductive time was analyzed, and the probable causes are discussed.

*Rast, Everette D.

1974. **Log and tree sawing times for hardwood mills.** USDA For. Serv. Res. Pap. NE-304. 17 p.

Data on 6,850 logs and 1,181 trees were analyzed to predict sawing times. For both logs and trees, regression equations were derived that express (in minutes) sawing time per log or tree and per Mbf. For trees, merchantable height is expressed in number of logs as well as in feet. One of the major uses for the tables of average sawing times is as a bench mark against which individual mills can make comparisons.

Rawson, James W.

1974. **Willows.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9 : 147-149.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Rexrode, Charles O.

1974. **Effect of pressure-injected oxydemetonmethyl, cacodylic acid, and 2,4-D amine on elm bark beetle populations in elms infected with Dutch elm disease.** USDA Plant Dis. Rep. 58(4) : 382-384.

Oxydemetonmethyl, cacodylic acid, and 2,4-D amine were pressure-injected into the sap stream of diseased American elm trees to determine the effectiveness of these chemicals in preventing development of elm bark beetles. Oxydemetonmethyl and cacodylic acid effected virtually complete control, whereas, 2,4-D amine effected no control.

*Rexrode, Charles O., and James W. Lockyer.

1974. **Laboratory assay of cacodylic acid and Meta-Systox-R on *Scolytus multistriatus* and *Pseudopityophthorus* sp.** USDA For. Serv. Res. Note NE-190. 4 p.

Cacodylic acid and Meta-Systox-R were applied to oak and elm bark beetle diets. Diets containing 900 to 1,000 ppm of cacodylic acid and diets containing 100 to 200 ppm of Meta-Systox-R killed both oak and elm bark beetles.

Roach, Benjamin A.

1974. **Selection cutting and group selection.** State Univ. N.Y. Coll. Environ. Sci. and For. Appl. For. Res. Inst. Misc. Rep. 5. 9 p.

Most people (including many foresters) have a very hazy idea of what selection cutting is. This paper explains what it is, how it works, and what must be done in applying it to avoid the pitfall of fluctuating yields.

Roach, Benjamin A.

1974. **Scheduling timber cutting for sustained yield of wood products and wildlife.** Univ. Mo. Timber and Wildl. Manage. Symp. Proc.: 33-43, illus. [Mo. Acad. Sci. Occas. Pap. 3.]

Adjustment of presently unbalanced age distribution is necessary for sustained yield of both timber and wildlife from eastern hardwood forests, but wildlife production requires regulation by much smaller units (several hundred to several thousand acres). This need not be prohibitively expensive if the age distribution in the small units approaches that of the forest as a whole. The key to successful regulation is long-term planning of cutting schedules for small areas.

Robinette, Sadie L.
1974. **Checkerberry wintergreen.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 20-22.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Robinette, Sadie L.
1974. **Mountain-laurel.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 102-105.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Robinette, Sadie L.
1974. **Rhododendron.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 113-115.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Rogers, Robert.
1974. **Blueberries.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 12-15.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Rollins, James A.
1974. **Viburnums.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 140-146.
A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Romberger, John A.
1974. **Book review of "Plant physiology: A treatise,"** Vol. 6C. Physiology of development: From seeds to sexuality. For. Sci. 20: 214.
This book completes the original plan of a major treatise on plant physiology totalling 5,800 pages in 11 books published over a 12-year period. F.C. Steward, editor, stressed the great need for synthesis and recognition of emerging pattern or order. Chapter authors attempted to answer that need. The review comments on the relative success and value of their efforts. It is noteworthy that the authors of the final chapter intimate that, in spite of recent progress in molecular biology, the molecular approach does not yet even remotely explain development.

Romberger, J.A., and R.A. Gregory.
1974. **Analytical morphogenesis and the physiology of flowering in trees.** Third North Amer. For. Biol. Workshop Proc.: 132-147. Ft. Collins, Colo.
A new approach to the study of flowering in trees is proposed and discussed. The rationale is based upon a working hypothesis that flowering is basically an example of differential morphogenesis in vegetative sporophyte tissue. Such differential morphogenesis is based upon changes in rates and distributions of meristematic activity. The latter can be analyzed and quantified by methods already used by the authors to analyze vegetative development of *Picea* seedlings.

*Ross, Terence L., and George H. Moeller.
1974. **Communicating rules in recreation areas.** USDA For. Serv. Res. Pap. NE-297. 12 p., illus.
Five hundred fifty-eight campers were surveyed on the Allegheny National Forest to determine their knowledge of rules governing recreation behavior. Most of them were uninformed about the rules. Results of the study suggest that previous camping experience, age, camping style, and residence significantly affect knowledge of rules. Campers who received rule brochure or saw posted signs had significantly higher scores on knowledge of rules than others. Concentrating communication efforts on adolescents, tent campers, low frequency-of-visit campers, and non-locals might produce immediate gains in knowledge about rules.

Rudolf, Paul O., and W.B. Leak.

1974. *FAGUS* **L.: Beech.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 401-405, illus.

Describes the occurrence, geographic races, flowering and fruiting, seed collection and treatment, germination, and nursery practice for the genus *Fagus*.

Safford, L.O.

1974. **Effect of fertilization on biomass and nutrient content of fine roots in a birch-beech-maple stand.** Plant and Soil 40: 349-363.

Deep rooting by northern hardwood species is hampered by infertility and toxicity problems in acid subsoils. In this study a surface-applied fertilizer treatment enriched the soil and stimulated root production throughout the soil profile, a significant implication for fertilizer use by forest managers.

Safford, L.O.

1974. **Seasonal variation in growth and nutrient content of yellow birch layer roots.** Third N. Am. For. Biol. Workshop Proc.: 351. Colo. State Univ.

In this study, root layers were established on nine yellow birch trees, and layer roots were harvested over two growing seasons. Biomass production per active layer did not vary greatly within or between the two growing seasons. Conversely, concentration of each element measured—N,P,K,Ca,Mg,Fe,Mn,Zn, and Al—varied either within or between seasons or both. This technique is a promising research tool for studies of root and tree nutrition.

Safford, L.O.

1974. *PICEA* **A. Dietr.: Spruce.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 587-597, illus.

A summary of growth habit, occurrence, and uses; geographic races and superior strains; flowering and fruiting; extraction and storage of seed; pregermination treatments and germination tests; and nursery practice.

*Safford, L.O., and S.M. Filip.

1974. **Biomass and nutrient content of 4-year-old fertilized and unfertilized northern hardwood stands.** Can. J. For. Res. 4: 549-554.

Biomass and nutrient content of natural stands of northern hardwood regeneration were measured 4 years after clearcutting. Pin cherry and shrubs made up a significant proportion of the biomass in both unfertilized and fertilized stands. Yet these stands are well stocked with large numbers of desirable commercial species, especially paper and yellow birch. However, fertilizer greatly stimulated pin cherry to the detriment of the commercial species. Paper birch was the only commercial species to increase in average dry weight on the fertilized area.

*Safford, L.O., Alex L. Shigo, and Marilyn Ashley.

1974. **Gradients of cation concentration in discolored and decayed wood of red maple.** Can. J. For. Res. 4: 435-440, illus.

Concentrations of K, Mn, Ca, Mg, and Na were systematically measured along columns of discolored and decayed wood associated with drill hole wounds in red maple. The discolored and decayed wood contained higher concentrations of all elements than either adjacent clear wood in the same tree or clear wood of unwounded trees. Different patterns of distribution between the elements suggest that these elements may have different roles in the discoloration and decay process.

Sardo, William H. Jr., and Walter B. Wallin.

1974. **The performance of wooden pallets in pallet exchange programs.** Natl. Wooden Pallet and Container Assoc., Washington, D.C. 37 p.

Twenty variations of design of 48x40-inch pallets were monitored during commercial shipping operations for 3 years to determine performance characteristics and cost per use. Results showed that cost per use is least when the pallets are of high quality. High-quality pallets can be constructed of a normal quality mix of shook, provided the shook is sorted to use the best quality as end boards and stringers, with the lower quality in the center. All species of wood may be used to build high-quality pallets, but the fastening system must be compatible with the species.

Sarles, Raymond L.

1974. **Using and marketing bark residues in the United States.** IUFRO V Meeting Proc. 1973 vol. 2: 911-917, illus. Cape Town, Republic of South Africa.

Both conifer and hardwood tree barks are processed in large volumes in the U.S. for several types and grades of mulches and soil conditioners, and the market is apparently growing. Unprocessed bark residues are used for various purposes in agriculture, industry, and construction; and these uses are growing. The variety of ways in which bark residues are now used suggests a host of opportunities for wood processors seeking answers to bark-disposal problems.

*Sarles, Raymond L.

1974. **The use and value of wood and bark residues in the Northeast,** *or* **"Thar's gold in them thar bark piles".** North. Logger 23(2): 22-23, 38-39, illus.

A study of the uses and markets for bark and other wood residues revealed that there are profitable ways to dispose of these sawmill wastes. Processing and packaging residues can open up money-making markets for the sawmill operator. Bark and wood residues are cheap sources of fuel when compared to fossil fuels at today's prices.

Schemnitz, Sanford D.

1974. **Sweetfern.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 138-139.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Schopmeyer, C.S., and W.B. Leak.

1974. *OSTRYA VIRGINIANA* **(Mill.) K. Koch: Eastern hophornbeam.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 564-565, illus.

Describes occurrence, flowering and fruiting, seed collection and treatment, germination, and nursery practice for the species *Ostrya virginiana.*

Schreiber, Lawrence R., and John W. Peacock.

1974. **Dutch elm disease and its control.** USDA Agric. Inf. Bull. 193. 15 p., illus.

Information about Dutch elm disease and its elm bark beetle vectors. Included are discussions of the history of both the disease and the beetle, disease symptoms, and beetle life history. Special emphasis is given to the latest techniques for control of the beetles (including techniques for spraying elms with methoxychlor and for sanitation to remove beetle breeding sites), and techniques for control of root-graft spread of the disease. The planting of elms resistant to the disease is also discussed, and resistant varieties now available are described.

Schreiner, Ernst J.

1974. **Poplars can be bred to order for mini-rotation fiber, timber and veneer production and for amenity plantings.** Northeast. For. Tree Improv. Conf. Proc. 21: 85-96, illus.

A review of the distribution of the genus *Populus* and a discussion of genetic improvement possibilities based on environmental adaptability, growth rates, lack of barriers to species crossability within and between sections, and ease of clonal propagation. Suggests that the genus *Populus* offers greater possibilities for genetic improvement than any other genus of forest tree, and a major improvement effort is easily justified and long overdue.

Schreiner, Ernst J.

1974. *POPULUS* **L.: Poplar.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 645-655, illus.

A summary of growth habit, occurrence, and use; geographic races, ecotypes, clones, and hybrids; superior clones and cultivars; flowering and fruiting; collection, extraction, and cleaning of seeds; drying and storage of seeds; and germination.

Scott, E.G., B.C. Bearch, M.L. Cunningham, and G.W. Wood.

1973. **Out of the mighty oak the enchanting rose.** Rose Annu. 38: 148-153, illus.

In greenhouse trials at West Virginia University, tea roses grown in hardwood bark-sawdust (1:1) media yielded cut roses equivalent in number and quality to roses grown in standard rose soil mix and peat-vermiculite mix. Soluble N in the form of $NH_4NO_3$, or a slow-release fertilizer like Osmocote, is required in bark-sawdust growing media to

offset initial nitrogen drag from the bark and sawdust and to supply the plants. Feeding of iron chelate (2 ounces per 100 square feet every 2 months) is also recommended for hardwood bark-sawdust media to offset iron deficiency and resulting chlorosis in roses.

Seegrist, Donald W.

1974. **Statistical models and estimators of the proportion of volume by log position.** For. Sci. 20: 257-362, illus.

A conditioned regression model for the proportion of volume by log position was proposed previously. In it, estimates of the conditioned regression coefficients were calculated by a step-by-step application of least squares. This paper presents the statistical theory for the earlier procedures. The estimators are shown to be linear combinations of multivariate least square estimators of the average proportion of volume in each log position. Expressions for the covariance matrix of the estimator are derived. Simultaneous estimators of the conditioned regression coefficients are derived by multiple coefficients are compared, using volume measurements on peeler logs from 680 loblolly pines.

*Seegrist, Donald W.

1974. **Weighted regression analysis and interval estimators.** USDA For. Serv. Res. Note NE-195. 5 p., illus.

A method for deriving the weighted least-squares estimators for the parameters of a multiple-regression model. Confidence intervals for expected values and prediction intervals for the means of future samples are given.

*Seliskar, Carl E., Glenn E. KenKnight, and Carol E. Bourne.

1974. **Mycoplasmalike organism associated with pecan bunch disease.** Phytopathology 64: 1269-1272, illus.

Pecan bunch, a widespread and serious disorder throughout the commercial range of southern pecan, *Carya illinoensis,* was formerly presumed to be virus-induced, but the consistent association of a mycoplasmalike organism (MLO) with diseased and not with healthy trees strongly points to MLO etiology. Pecan bunch is not systemic throughout the tree. MLO, found in phloem sieve elements and companion cells of stems and leaves of affected trees, are most abundant in severely broomed material and are rarely observed in nonsymptomatic tissues. They are pleqmorphic, vary in size from 80 to 800 nm, contain ribosomal bodies and fibrillar material typical of DNA, and are delimited by a tripartite unit membrane. Spherical and oval forms are most common, but filamentous forms can be seen near sieve plates.

*Sendak, Paul E.

1974. **Analysis of pure maple syrup consumers.** USDA For. Serv. Res. Pap. NE-295. 11 p., illus.

Users of pure maple syrup who live in the syrup-producing area differ from consumers in other parts of the United States in their pattern of syrup use and purchase. This survey analyzes differences in user attitudes and habits and in the packaging and distribution of syrup.

*Sendak, Paul E., and Mariafranca Morselli.

1974. **Control of fancy maple syrup quality in the retail package.** Natl. Maple Syrup Dig. 13(4): 14-18, illus.

An experiment is described for determining the effects of retail containers on the quality of fancy-grade pure maple syrup. Storage temperature, light, and storage time were varied to test their effects on the syrup. If a good-quality fancy syrup is stored in the retail container at room temperature, and has been properly hotpacked, the quality of the syrup will be maintained satisfactorily for at least 6 months in all the containers tested.

Shafer, Elwood L., Jr.

1974. **The average camper who doesn't exist.** *In* Land & Leisure: concepts and methods in outdoor recreation: 112-129, illus.

A questionnaire survey of campers at five New York State campgrounds revealed that campers vary so much—not only from campground to campground, but also at the same campground from month to month—that data from such studies cannot be lumped together in any meaningful way. Causes of the variation are discussed. The author recom-

mends that future camper surveys should be stratified by months and similar campgrounds.

*Shafer, Elwood L., Jr., and George H. Moeller.

1974. **Through the looking glass . . . in environmental management.** Parks & Recreation 9 (2) : 20-23, 48-49, illus.

The trend of many institutions to incorporate some form of the word *environment* in their official titles typifies society's concern for the broad range of today's environmental issues. This paper is a think-piece for those professionals who would seriously address themselves to the integration of recreation with a broader range of environmental issues and policies—both today and in the future. Forecasts are made on related social, technological, and institutional events that are likely to occur in the future.

*Shafer, Elwood L., and George H. Moeller.

1974. **Wildlife priorities and benefits: now, 2000, and beyond.** North Am. Wildl. Nat. Resour. Conf. Trans. 39: 208-215.

In a survey, planners rated wildlife values high only for wildland management situations. For city recreation environments, wildlife values were rated low or negligible in priority. Probable social attitudes and events that may influence wildlife management in the future are described. Although hunting will continue for some time into the future as an important use of wildlife resources, nonconsumptive uses of wildlife will be the primary social value by the year 2000.

*Shafer, Elwood L., George H. Moeller, and Russell E. Getty.

1974. **Future leisure environments.** USDA For. Serv. Res. Pap. NE-301. 16 p., illus.

As an aid to policy- and decision-making about future environmental problems, a panel of experts was asked to predict the probabilities of future events associated with natural-resource management, wildland-recreation management, environmental pollution, population-workforce-leisure, and urban environment.

Shafer, Elwood L., George Moeller, Douglas A. Morrison, and Russell Getty.

1974. **Recreation, resources, and right decisions.** USDA For. Serv. Res. Pap. NE-293. 16 p., illus.

The authors present a series of relevance trees that pinpoint, in terms of interacting social and physical site variables, the important priorities in today's urban, rural, and wildland resource-management decisions. The results of this research provide a fairly simple structure for recreation managers to assess the effect of present and future social and political conditions on recreation planning and development decisions.

*Shafer, Elwood L., Jr., and Thomas A. Richards.

1974. **A comparison of viewer reactions to outdoor scenes and photographs of those scenes.** USDA For. Serv. Res. Pap. NE-302. 26 p., illus.

A color-slide projection or photograph can be used to determine reactions to an actual scene if the presentation adequately includes most of the elements in the scene. Eight kinds of scenes were subjected to three different types of presentation: (1) viewing the actual scenes, (2) viewing color slides of the scenes, and (3) viewing color photographs of the scenes. For each scene, responses to each of the three treatments were compared statistically and graphically.

Sharon, E.M.

1974. **Anaerobic environment enhances the detection of bacteria in tissues associated with wounds in living trees.** (Abstr.) Phytopathology 64: 585.

A total of 581 chips 2x2x5 mm were cut from discolored tissues of natural wounds on *Quercus alba, Q. rubra,* and *Acer rubrum,* and 324 chips from unwounded control trees. Chips were incubated for 5 days at 30°C, both aerobically and anaerobically on agar medium. Only 8 percent of the chips from control trees yielded bacteria, but yield of bacteria from chips from wounded trees doubled in each medium in the anaerobic environment.

*Sharon, E.M.

1974. **An altered pattern of enzyme activity in tissues associated with wounds in** *Acer saccharum.* Physiol. Plant Pathol. 4: 307-312, illus.

Sites of nicotinamide adenine dinucleotide (NAD)-linked respiratory activity in sugar maple tissues after wounding were shown by the histochemical localization of NAD diaphorase. The enzymic dehydrogenation of reduced NAD conjoined with the reduction of nitro-blue tetrazolium resulted in intracellular deposits of diformazans at sites of diaphorase activity. After wounding, diformazans formed in parenchyma cells contiguous with the wound and developed in previous years. Intense diformazan deposits formed in specific parenchyma "contact cells" that connected the vascular and parenchyma systems.

*Sharon, Edward M., and Alex L. Shigo.

1974. **A method for studying the relationship of wounding and microorganisms to the discoloration process in living trees.** Can. J. Forest Res. 4: 146-148, illus.

A plug was designed to allow the exchange of atmospheric air and moisture but suppress infection by microorganisms during the development of discoloration associated with wounds in living trees. The design is described.

Sharp, Ward M.

1974. **Ecology of shrubs and vines.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 2-5.

A discussion of the growth forms of shrubs and vines and the principal environmental factors that interact on them: (1) physical —sunlight, soil and moisture, temperature, and fire; and (2) biological factors—browsing, insects and diseases, and seed dispersal by animals.

Sharp, Ward M.

1974. **Hawthorns.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 59-64.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

*Shigo, Alex L.

1974. **A new look at decay in trees.** North. Logger 23(4) : 10, 11, 38, 39.

A new expanded concept of decay and a new meter that detects decay in living trees gives new opportunities for control of decays, the major cause of damage to wood. Details on the concept and meter are given, especially as they relate to discoloration and decay in northern hardwoods.

*Shigo, Alex L.

1974. **Effects of manganese, calcium, zinc, and iron on growth and pigmentation of** *Trichocladium canadense, Phialophora melinii, Hypoxylon rubiginosum, Daldinia concentrica,* **and** *Cytospora decipiens.* Mycologia 66(2) : 339-341.

Some of the fungi isolated most frequently from discolored wood associated with wounds in sugar maple, red maple, yellow birch, paper birch, American beech, and white ash, are *Trichocladium canadense, Phialophora melinii, Hypoxylon rubiginosum, Cytospora decipiens* and *Daldinia concentrica.* These fungi grew well in high concentrations of manganese, calcium, zinc, and iron. These fungi may be aggressive wound invaders because they have adapted to the high concentrations of minerals that accumulate in tissues as they die, discolor, and decay.

*Shigo, Alex L.

1974. **Relative abilities of** *Phialophora melinii, Fomes connatus,* **and** *F. igniarius* **to invade freshly wounded tissues of** *Acer rubrum.* Phytopathology 64: 708-710, illus.

*Phialophora melinii, Fomes connatus,* and *F. igniarius* were inoculated into wounds inflicted in *Acer rubrum* in June. After 12 weeks, *P. melinii* was isolated from 50 of 54 wounds inoculated with it. *F. connatus* was isolated from one wood chip of 874 from 72 wounds inoculated with it, and *F. igniarius* was not isolated. Bacteria, *Graphium* sp. and *Cytospora* sp. were isolated frequently. *Phialophora melinii, Graphium* sp., *Cytospora* sp., and bacteria were pioneer microorganisms infecting the type of wounds inflicted in *A. rubrum* in June, while *F. connatus* and *F. igniarius* were not.

*Shigo, Alex L., and Alex Shigo.

1974. **Detection of discoloration and decay in living trees and utility poles.** USDA For. Serv. Res. Pap. NE-294. 11 p., illus.

A method is described for detecting discoloration and decay in trees and utility poles. The electrical resistance to a pulsed current is less in decayed wood than in sound wood. A

meter has been developed, a "Shigometer", that delivers a pulsed current and measures the resistance to it. A probe attached to the meter by a flexible cable is inserted into a hole, 2.4 mm in diameter, drilled into the wood. When the probe tip is pushed inward and it moves from sound wood to discolored wood that is above the fiber-saturation point, the resistance measured in ohms on the meter decreases abruptly.

Shutts, Lynn M.

1974. **Summer grape.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 52-53.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Smith, Hanley K.

1974. **Sumacs.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 134-137.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Smith, Robert L.

1974. **Greenbriers.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 54-58.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Smithberg, Margaret.

1974. **Red-osier dogwood.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 44-47.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Smithberg, Margaret, and John D. Gill.

1974. **Roses.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 116-121.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Solomon, Dale S.

1974. **Simulation of the development of natural and silviculturally treated stands of even-aged northern hardwoods.** *In* Growth models for tree and stand simulation. IUFRO Work Party Proc. S4.01-4: 327-352, illus. Swed. R. Coll. For. Res. Note 30. Stockholm.

A description of a computer programming system developed to represent a summary and synthesis of appropriate data for simulating the development and treatment of even-aged northern hardwoods in New England.

Solomon, J.C., and C.J. Hay.

1974. **Annotated bibliography of the carpenterworm** *(Prionoxytus robiniae.)* USDA Forest Serv. Gen. Tech. Rep. SO-4. 13 p.

The carpenterworm, distributed widely throughout the United States and southern Canada, causes serious borer defect in the wood of living hardwood sawtimber, especially oak. Occasionally fruit trees and ornamentals are attacked. The bibliography was prepared for entomologists, foresters, and pest-control personnel.

*Sonderman, David L.

1974. **A simple and inexpensive pulsing device for data-recording cameras.** USDA For. Serv. Res. Note NE-183. 4 p., illus.

In some areas of forestry and wood-utilization research, use of automatic data-recording equipment has become commonplace. This note describes the basic electronic components needed to modify an existing intervalometer into a simplified pulsing device for controlling an automatic data-recording camera. The pulsing device is easily assembled and inexpensive when compared to similar proprietary units.

Spomer, L. Art.

1974. **How much hardwood bark is necessary for proper container-soil amendment?** For. Prod. J. 25(2): 57-59, illus.

Because particle shapes and sizes of hardwood bark soil amendment vary greatly between sources and lots, formulations for bark-soil container-growing media that are based on empirical trials are valid only for each lot of bark. This paper describes a method that overcomes this difficulty by predicting the porosity of any hardwood-bark soil mixture as an index for determining the optimum amount of bark to use. The concept is demonstrated with diagrams of bark-soil mixtures.

*Staley, David H., William R. Holt, and William N. Cannon, Jr.

1974. **Necessary and sufficient condition for a model insect population to go to extinction.** Bull. Math. Biol. 36: 527-533, illus.

A necessary and sufficient condition on the parameters for a model population to become extinct is presented. The mathematical model describes an insect population with overlapping generations where the females are polyandrous and the males are subject to autosterilization. The relationship between the values of the parameters of the model and the time to extinction is illustrated.

Stearns, Forest W.

1974. **Hazels.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 65-70.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Steinhagen, Hans-Peter.

1974. **Effect of kiln air velocity, at various moisture content levels, on drying rate of 4/4 yellow-poplar sapwood.** For. Prod. J. 24(4): 45-47, illus.

Economy in kiln-drying lumber necessitates the use of optimum air velocities for different levels of lumber moisture content. This study determined that for 4/4 yellow-poplar sapwood below 40 percent moisture content, satisfactory drying rates can be maintained with an air velocity of only 250 feet per minute. But at moisture contents above 40 percent, increasing the air velocity by about 500 feet per minute results in significantly faster drying rates.

Stern, E.G.

1974. **Design of pallet deckboard-stringer joints. Part 1: Aspen-pallet joints and aspen pallets.** Va. Polytech. Inst. and State Univ. Wood Res. and Wood Constr. Lab., Pallet and Container Res. Cent. 126. 48 p., illus.

Aspen lumber is representative of the lighter wood species readily available for pallet manufacture in many localities. Aspen pallets can be made 1⅓ times stiffer and 1 1/5 times more rigid than oak pallets and thus have an increased service life if wider aspen stringers are used and if the leading-edge deckboards are fastened with more and larger nails.

Stern, E.G.

1974. **Recent pallet fastening research can reduce pallet costs.** Va. Polytech. Inst. and State Univ. Wood Res. and Wood Constr. Lab., Pallet and Container Res. Cent. 128. 8 p., illus.

The advantages are presented of using hardened-steel 3-inch versus 2½-inch pallet nails; pallet nails with four helical thread flutes versus nails with five flutes; helically threaded versus helically fluted hardened-steel nails; and plastic-polymer coated 2½-inch, 15-gage, 7/16 inch crown pallet staples.

Stern, E. George, and Walter B. Wallin.

1974. **How pallets stand.** Purch. World 18 (9): 68.

Although the supply of wooden pallets has improved, it is expected to remain snug over the next few years. It is suggested that pallet users take a closer look at the economics of pallet use. Pallet life increases much faster than price, up to $10 per pallet. Therefore better and more expensive wooden pallets cost less per use. Compared with other materials, wooden pallets still offer a hard-to-beat economic advantage.

Tabor, Christopher A.

1974. **Review of "The life history of Douglas-fir",** by George S. Allen and John N. Owens (1972). For. Sci. 20: 104.

This book was prepared by John N. Owens on the basis of materials left by the late George S. Allen. This collection was richly supplemented by Owens' own experience and materials. The result is a comprehensive treatise of great value to developmental biologists and to many other forest scientists as well. The book includes an impressive collection of photographs.

Tabor, Christopher A.

1974. **Review of "Organogenesis of flowers: A photographic text-atlas",** by Rolf Sattler (1973). For. Sci. 20: 56.

This book is a photo-atlas arranged as a catalog of angiosperm floral parts in various stages of development. More than 1,000 photographs illustrate the diverse forms that the organs can take and also convey a sense of

dynamics. The descriptive text emphasizes sequential changes and makes a useful technical book of what otherwise might appeal mostly as an art collection.

Talerico, R.L., and T.A. Skratt.

1974. **Gypsy moth defoliation: can we segregate damage levels from aerial photographs?** Univ. Maine and Am. Soc. Photogramm. 4th Bienn. Workshop Color Aer. Photogr. Proc. 1973: 233-234. Orono, Maine.

The authors describe the defoliation of hardwood stands by the gypsy moth (*Porthetria dispar* L.) and the development of a method for characterizing this defoliation. A brief account of the history of the gypsy moth, its seasonal development, and the gypsy moth research and development program are presented, ending with some ideas and questions about attacking this problem.

Thomas, Jack Ward, and Richard M. DeGraaf.

1974. **Raccoons on the roof.** *In* Gardening with wildlife: 153-168. Natl. Wildl. Fed., Washington, D.C. 190 p.

Advice to homeowners who have problems with wildlife around their property. Methods are suggested for keeping birds and mammals out of attics, gardens, and lawns. Wildlife provides pleasures that far outweigh the minor problems that occasionally arise and that normally can be prevented easily and inexpensively.

Thomas, Jack Ward, Richard M. DeGraaf, and Joseph C. Mawson.

1974. **A technique for evaluating bird habitat.** *In* Wildlife in an urbanizing environment: 159-162. Univ. Mass. Holdsworth Nat. Resour. Cent. Plann. and Dev. Ser. 28. Amherst.

A method was developed for studying habitats of several songbird species simultaneously. Ten species were censused 9 times at 80 roadside plots in Amherst, Mass., and habitat attributes were measured. The vegetative layers whose volumes were significantly correlated with the abundance of each species were designated as important habitat variables. Other habitat characteristics are also discussed.

Thomas, Jack Ward, and Ronald A. Dixon.

1974. **Cemetery Ecology.** *In* Wildlife in an urbanizing environment: 107-110. Univ. Mass. Holdsworth Nat. Resour. Cent. Plann. and Dev. Ser. 28. Amherst.

Urban cemeteries provide scarce open space that can be managed for recreation and wildlife to benefit urban people. During 200 hours of study, several thousand people were observed participating in more than two dozen recreational activities in 50 Boston cemeteries. Ninety-five bird and 20 mammal species were identified. Deliberate management can enhance recreation and wildlife values of cemeteries.

*Timson, Floyd G.

1974. **Weight and volume variation in truckloads of logs hauled in the central Appalachians.** USDA For. Serv. Res. Pap. NE-300. 9 p., illus.

Discusses the variation in weight and volume found among loads of logs hauled by truck in the central Appalachian Mountains. Elements that can cause load variation are discussed. Recommendations for reducing variation and increasing payload are included.

Townsend, A.M., and L.S. Dochinger.

1974. **Relationship of seed source and developmental stage to the ozone tolerance of *Acer rubrum* seedlings.** Atmos. Environ. 8: 957-964.

Air-pollution damage to trees is of increasing economic and biological importance. Significant tolerance to ozone was demonstrated by red maple progenies. The stability in response to ozone fumigation during various plant and leaf ontogenetic stages signifies strong genetic control. These findings will facilitate the selection of ozone-tolerant seed sources and seedlings of red maple trees.

*Trimble, G. R., Jr.

1974. **Response to crop-tree release by 7-year-old stems of red maple stump sprouts and northern red oak advance reproduction.** USDA For. Serv. Res. Pap. NE-303. 6 p.

Study results from a crop-tree release of red maple stump sprouts and northern red oak

advance reproduction in a 7-year-old hardwood stand on a fair site indicated that the release: (1) had no effect on the height growth of either species; (2) did positively favor diameter growth of the red maple, but did not affect diameter growth of the red oak; and (3) had little effect on crown position of red oak, but favored retention of dominance among codominant red maple sprouts.

*Trimble, George R., Jr., Joseph J. Mendel, and Richard A. Kennell.

1974. **A procedure for selection marking in hardwoods combining silvicultural considerations with economic guidelines.** USDA For. Serv. Res. Pap. NE-292. 13 p., illus.

This method of applying individual-tree selection cutting in hardwood stands incorporates silvicultural considerations with economic guidelines for selecting trees for cutting. The economic guidelines are rates of return, which were developed from growth and tree-quality data for nine major species. Actual tree stumpage values were determined, working back from standard lumber prices, by deducting conversion costs.

*Trimble, George R., Jr., James H. Patric, John D. Gill, George H. Moeller, and James N. Kochenderfer.

1974. **Some options for managing forest land in the central Appalachians.** USDA For. Serv. Gen. Tech. Rep. NE-12. 42 p., illus.

The multiple-use principle has been recognized by many people and for many years as a desirable approach to forest management. This publication is intended to present multiple-use options for managing forest land in the central Appalachians. These multiple-use options are presented by ecosystems for the following forest uses: timber, water, visual appeal, and wildlife.

*Trimble, G.R., Jr., and E.H. Tryon.

1974. **Grapevines a serious obstacle to timber production on good hardwood sites in Appalachia.** North. Logger 23(5): 22, 23, 44, illus.

Wild grapevines are damaging to timber production in Appalachian hardwood stands. Although grapevines reproduce by both seeds and sprouts, damage from sprouts is more serious because they grow so much faster than seedlings. Because grapevines are shade intolerant, they are much more of a problem after clearcutting than after selection cutting. Grapevines are more common on the better sites.

Troendle, C.A., G.M. Aubertin, and J.N. Kochenderfer.

1974. **Decomposition of the forest floor following deforestation and annual herbiciding.** Agron. Abstr. Am. Soc. Agron. Meet. Div. S-7: 179.

Half of a 23-ha watershed was deforested and annually treated with herbicides to prevent regrowth. Samples of the L, F and H, $A_1$ (0-7.5 cm), and $A_3$ (7.5-15.0 cm) horizons were collected for 4 years. The litter (L) was depleted after the first year. Loss on ignition in the F and H, $A_1$, and $A_3$ horizons and root weight decreased linearly with time. Settling increased the weight of mineral soil sampled in the fixed volume, resulting in little if any net change in organic matter in the upper 15 cm of mineral soil.

Vilkitis, James R.

1974. **Cherries.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 23-25.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Vogel, Willis G.

1974. **All-season seeding of herbaceous vegetation for cover on Appalachian strip-mine spoils.** Natl. Coal Assoc. Res. & Appl. Tech. Symp. on Mined-Land Reclaim. Proc. 2: 175-188. Louisville, Ky.

Mixtures of temporary (quick cover) and long-lived (permanent) herbaceous species were sown periodically throughout the year on strip-mine spoils in eastern Kentucky. Fair to excellent cover was established within 45 to 60 days after seeding from March 1 to October 15, although establishment was a little slower for some of the seedings made in July and August. Seedings in December and February were less successful than those in March and April. Seedbed preparation is essential for successful establishment of seeded vegetation.

Vogel, Willis G.

1974. *LESPEDEZA* **Michx.: Lespedeza.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 488-490, illus.

A brief description of this genus, including growth habit, occurrence, and use; superior strains; flowering and fruiting; collection of fruits and extraction and storage of seed; pregermination treatments; germination tests; and nursery and field practices.

*Vozzo, J.A., and Edward Hacskaylo.

1974. **Endo- and Ectomycorrhizal associations in five *populus* species.** Torrey Bot. Club Bull. 101 (4) : 182-186, illus.

After inoculation with mycorrhizal fungi in soil, *Populus fremontii, P. grandidentata,* and *P. tremuloides* formed ectomycorrhizae; *P. heterophylla* formed no mycorrhizae; *P. deltoides* and *P. deltoides* var. occidentalis formed both ecto- and endomycorrhizae. Spores isolated from endomycorrhizal *P. deltoides* appear to be *Endogone* species. Respiration rates of *P. deltoides* were 2.8$\mu$ 1 $0_2$/mg/hr for nonmycorrhizal roots and 3.0$\mu$ 1 for endomycorrhizae. Histochemical differences in the two kinds of roots suggest that protein synthesis is more active with mycorrhizae than with nonmycorrhizal roots.

Wallin, W.B., and E.G. Stern.

1974. **Tentative nailing standards for warehouse and exchange pallets.** Va. Polytech. and State Univ. Wood Res. and Wood Constr. Lab., Pallet and Container Res. Cent. 129. 16 p., illus.

When wood species of different densities are used for the construction of wooden pallets, different sizes and numbers of nails are, under given conditions, needed to assemble pallets of comparable strength. The standards presented are recommended for use in designing pallets for specific performance requirements.

*Walters, Russell S., and William J. Gabriel.

1974. **Sugar maple sap-flow rate and sap volume.** Natl. Maple Syrup Dig. 13(3) : 12-14, illus.

Sap-flow rate is closely correlated with the sap volume produced by dormant sugar maple trees and can be used in making phenotypic selections of trees for superior sap production.

Walton, G.S., and C.J. DeMars.

1974. **Empirical methods in the evaluation of estimators.** *In* Statistics in forestry research: 161-164. IUFRO Fourth Conf. Advis. Group For. Stat. Vancouver, B.C.

The authors discuss the problem of selecting estimators of density and survival by making use of data on a forest-defoliating larva, the spruce budworm. Various estimators are compared. The results show that, among the estimators considered, ratio-type estimators are superior in terms of bias and variance. The methods used in making comparisons, particularly simulation, are generally applicable to situations in which data appropriate for making estimates are on hand.

Wargo, Philip M.

1974. **Lysis of the cell wall of *A. mellea* by enzymes from forest trees.** (Abstr.) Phytopathology 64: 588.

Chitinase and ß,1-3, glucanase were extracted from healthy tissue of both stem and root of sugar maple, red oak, black oak, and white oak. Yields were higher from the inner bark. Enzyme extracts, concentrated by ammonium sulfate precipitation, dissolved the cell wall of *Armillaria mellea.* The presence of these enzymes in trees and their ability to lyse the cell walls of *A. mellea* suggest a system in trees that may account for the resistance of healthy tissues to invasion by *A. mellea* and possibly other organisms.

Wargo, Philip M., and David R. Houston.

1974. **Infection of defoliated sugar maple trees by *Armillaria mellea.*** Phytopathology 64: 817-822, illus.

Manually-defoliated and insect-defoliated trees were inoculated with *Armillaria* mellea to determine the influence of time of season and frequency of defoliation on root invasion by the fungus. Insect populations collapsed and caused only light defoliation. This resulted in a low incidence of infection of trees by *A. mellea* and low tree mortality. Manual defoliation in June or July resulted in more infections and higher mortality than did manual defoliation in August. The incidence of infection was higher when trees were defoliated for two consecutive years than when they were defoliated once. Not all dead trees were infected by *A. mellea.* There was evi-

dence that *Stegonosporium ovatum* may hasten death of stem tissues severely stressed by defoliation.

Wartluft, Jeffrey L.

1974. **Baling hardwood bark with a vertical baler.** North. Logger 22(12) : 22, illus.

The vertical baler, designed to bale peat moss and similar materials, can also be used to bale hogged hardwood bark for use as mulch. A plastic-covered bale holds about 4 cubic feet of compressed bark versus 3 cubic feet of loose bark in a bag—a cost saving in packaging.

*Wartluft, Jeffrey L.

1974. **Yield table for hardwood bark residue.** USDA For. Serv. Res. Note NE-199. 4 p., illus.

Bark residue weights are tabulated for eight species of hardwood sawlogs according to log volume by the Doyle International ¼-inch and Scribner decimal-C log rules. Factors are provided for converting from weight in pounds to volume in cubic yards.

Watt, Richard F., Kenneth A. Brinkman, and B.A. Roach.

1973. **Oak-hickory.** *In* Silvicultural systems for the major forest types of the United States. USDA For. Serv. Agric. Handb. 445: 66-69.

A primer of basic silviculture applicable in the oak-hickory type of the east-central United States.

Wendel, G.W.

1974. *CELASTRUS SCANDENS* **L.: American bittersweet.** *In* Seeds of woody plants in the United States. USDA Agric. Handb. 450: 295-297, illus.

Growth, habit, occurrence, and use of *Celastrus scandens* L. are described, as well as the phenology, collection of fruit, extraction, and storage of seed. Pregermination treatments, germination testing, and nursery practices are also described.

*Wendel, George W., James N. Kochenderfer, and Cleveland J. Biller.

1974. **Skyline cable logging in West Virginia.** North. Logger 22(12) : 14-15, illus.

This article describes a trial of a mobile skyline cable logging system in the Appalachian Mountains of north-central West Virginia. Logs were yarded from a clearcut area and a selectively-cut area with minimal surface disturbance. Residual stand damages in the selectively-cut area was judged to be less than with other logging methods. Logs were yarded from 75 feet on each side of the skyline in the selectively-cut area and from 100 feet in the clearcut area. With an experienced 5-man crew, set up and take-down can be accomplished in 2 to 3 hours. The major advantage of the system is the elimination of many closely-spaced skid roads when logging in steep mountain terrain.

White, James R., and William T. Plass.

1974. **Sediment control using modified mining and regrading methods and sediment control structures.** Second Res. & Appl. Technol. Symp. on Mined-Land Reclam. Proc.: 117-123. Louisville, Ky.

Effective sediment control on surface-mined lands requires detailed planning before permit application and systematic implementation of all plans. In this case history, mining plans included head-of-the-hollow fills, control of outslope length, and controlled placement of overburden materials. Sediment-control impoundments removed 60 percent of the suspended solids resulting from low- to moderate-intensity storm events. These structures were not effective for high-intensity storms.

Wilkinson, Ronald C.

1974. **Realized and estimated efficiency of early selection in hybrid poplar clonal tests.** Northeast. For. Tree Improv. Conf. Proc. 21: 26-32.

Hybrid poplar clonal tests were evaluated for effectiveness of early selection for mature (15-year) height and for comparing predicted and observed mature responses to early selection. Selection of hybrid poplar clones for total height at 1 or 4 years in clonal tests may result in negative selection differentials at 15 years. Broad-sense heritabilities and genetic correlation are reliable for predicting the mature response to early selection, but they are applicable only to a limited range of sites and genotypes.

Williamson, Robert D.

1974. **Birds in Washington, D.C.** *In* Wildlife in an urbanizing environment: 131-136. Univ. Mass. Holdsworth Nat. Resour. Cent. Plann. and Dev. Ser. 28. Amherst.

The occurrence and distribution of songbirds was measured in neighborhoods adjacent to Rock Creek Park in Washington, D.C. Species included cardinals, mockingbirds, catbirds, wood thrushes, house sparrows, pigeons, starlings, robins, blue jays, and song sparrows. The number of birds seen was correlated with vegetative, socioeconomic, and demographic variables.

Wilson, C.L., and A.L. Shigo.

1974. **Dispelling tree myths.** Plants and Gard. 29(4): 14-15.

Some practices in arboriculture are based wholly or partly on myth rather than scientific facts. For example, one myth is that goose eggs placed around the roots of an elm tree will cure it of Dutch elm disease (for which there is no known cure). Filling a cavity in a tree will not stop decay. Wound dressings do not stop decay development. More research and scientific facts are needed rather than myths.

Wodzicki, T.J., and Alina B. Wodzicki.

1973. **Auxin stimulation of cambial activity in *Pinus silvestris*. II. Dependence upon basipetal transport.** Physiol. Plant. 29: 288-292.

The natural auxin content in the cambial region of large *Pinus silvestris* trees was determined at intervals throughout the year. No significant seasonal change in concentration of extractable auxin could be detected. Decapitation and girdling experiments produced severe reductions in cambial activity and in auxin level. The activity pattern of extracted pine auxin was not the same as that of synthetic indole-acetic aicd as determined by bioassays.

Wodzicki, T.J., and S. Zajaczkowski.

1973. **Effect of auxin on xylem tracheids differentiation in decapitated stems of *Pinus silvestris* L. and its interaction with some vitamins and growth regulators.** Acta Soc. Bot. Pol. 43: 129-148.

The possible basis of the seasonal variation in response of cambium or differentiating tracheids to auxin was studied by applying known substances in lanolin to the cut surfaces of decapitated trees. None of the effects obtained was significant enough to indicate involvement in seasonal changes in responsivity. Some of the results, however, are relevant to clarifying the role of auxin in tracheid development.

*Wolf, Charles H.

1974. **The effect of monetary incentives on absenteeism: a case study.** USDA For. Serv. Res. Pap. NE-291. 4 p.

An attendance bonus paid by a wood-processing firm was studied to determine its effectiveness in reducing absenteeism. Employees were divided into permanent and short-term groups, and their responses to the bonus were studied, using nonparametric tests. The evidence suggested that the incentive favorably influenced the work attendance of only the permanent group. Recommendations are made for future research.

Wolgast, Leonard J.

1974. **Bear oak.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 108-110.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Wollerman, Edward H.

1974. **Elm bark beetle dispersal studies.** Entomol. Soc. Am. North Cent. Branch Annu. Meet. 29: 177. Des Moines, Iowa.

Dispersal of the smaller European elm bark beetle in a 100-acre treeless area was investigated by tagging large numbers with P-32 and releasing. Dispersal was determined by use of 40 traps holding freshly infested elm wood as an attractant. In three releases the recoveries were 1 percent to 5 percent. About half the recoveries were in the nearest eight-trap circle of 264 feet radius. The remainder were found in almost every trap up to ¼ mile away.

Wood, Gene W.

1974. **Witch-hazel.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 154-157.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Wood, Gene W.

1974. **Common spicebush.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 129-131.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

*Worley, David P.

1974. **A handy guide to rate of increase interpretations.** USDA For. Serv. Res. Note NE-187. 3 p.

Compound interest tables are reduced to a single 3x5 card for field use. Examples are given to illustrate the table's use.

Worley, D. Michael, and Charles M. Nixon.

1974. **Elders.** *In* Shrubs and vines for Northeastern wildlife. USDA For. Serv. Gen. Tech. Rep. NE-9: 48-51.

A brief description of the range, habitat, life history, use by wildlife, propagation, and management.

Wu, Kent Y-t., and E.A. McGinnes, Jr.

1974. **Intra-incremental studies of methylation in scarlet oak.** Wood Sci. 7(2): 92-98.

A scarlet oak tree was sectioned, and comparisons were made across and between growth rings for content of lignin, lignin methoxyl, and wood methoxyl. Lignin content followed by hemicellulose methoxyl content are the most important variables for determining wood methoxyl content. Latewood lignin contained more methoxyl than earlywood lignin. However, no differences were established between sapwood and heartwood zones for the sampled tree.

*Yawney, Harry W., and Clayton M. Carl, Jr.

1974. **Storage requirements for sugar maple seeds.** USDA For. Serv. Res. Pap. NE-298. 7 p., illus.

Sugar maple seeds, collected from three trees in northern Vermont, were stored at four temperatures (18, 7, 2 and —10°C) in combination with four seed moisture contents (35, 25, 17 and 10 percent). Seed moisture content and storage temperature significantly affected keeping ability, and these factors were highly interrelated. Seeds from all trees kept best at the lowest temperature and lowest moisture content tested.

Yawney, Harry W., and Edward P. Johnson.

1974. **Protecting planted sugar maple seedlings from deer browsing.** Hardwood Res. Counc. Annu. Hardwood Symp. 2. Cashiers, N. C.

Animal damage is a major factor affecting the success of hardwood plantings. The devices tested in this study—straight wire, metal shield, and wire spines—were not effective in protecting planted 2-0 sugar maple seedlings from deer browsing. It was concluded that an alternative might be to use planting stock that is at least 6 feet high.

Zajaczkowski, Stefan.

1973. **Auxin stimulation of cambial activity in *Pinus silvestris*. I. The differential cambial response.** Physiol. Plant. 29: 281-287.

Isolated stem segments of *Pinus silvestris* produce new xylem for about 5 weeks in sterile culture if sucrose and auxin are supplied. The response of the cambium varies with the seasons and with the position on the tree from which the segment was taken. The relation between concentration of auxin and activity of the cambium, however, is complex and involves changes in responsivity of the cambium to auxin.

Northeastern Forest Experiment Station.

1975. **1974 at the Northeastern Station.**
Northeast. For. Exp. Stn., Upper Darby, Pa.
48 p. (USDA For. Serv. Gen. Tech. Rep. NE-18)

A summary report on highlights of research activities and accomplishments by the Experiment Station in 1974, including an annotated list of publications.

(74-75): 945.4: (047.1)

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1975. **1974 at the Northeastern Station.**
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# Interim Guide to Regeneration of ALLEGHENY HARDWOODS

by David A. Marquis
Ted J. Grisez
John C. Bjorkbom
Benjamin A. Roach

JAN 20

USDA FOREST SERVICE GENERAL TECHNICAL REPORT NE-19
1975

FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
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# Interim Guide to Regeneration of ALLEGHENY HARDWOODS


## ABSTRACT

Regeneration of Allegheny hardwoods is difficult to obtain because of excessive deer browsing on tree seedlings. Satisfactory regeneration is obtained after clearcutting only in stands where advance seedlings are abundant before cutting. Where advance seedlings are sparse, shelterwood cutting will often increase their numbers, provided that competition from grasses, ferns, beech root suckers, and striped maple is not excessive. Soil drainage and the importance of esthetic and recreation uses also affect the choice of silvicultural system and cutting procedure. In this paper, we provide guides needed for evaluating the regeneration potential and prescribing the most appropriate treatment for cherry-maple stands on the Allegheny Plateau of Pennsylvania and New York.

# Regeneration of Allegheny Hardwoods

REGENERATION is often difficult to obtain after harvest cutting in the cherry-maple forests of the Allegheny Plateau of Pennsylvania and New York. Surveys of clearcuttings made in the late 1960s show that only about half of these cutover areas are reproducing satisfactorily *(Grisez and Peace 1973)*. Excessive browsing of tree seedlings by an unusually large deer herd is the major cause of these failures *(Marquis 1975; Jordan 1967; Shafer et al. 1961; Grisez 1957; Bennett 1957; Frontz 1930)*.

Good reproduction sometimes develops after clearcutting in spite of deer browsing *(Husch 1954; Hough 1953; Ostrom 1938; Elliot 1927)*. More recent research has shown that the number of advance seedlings present before cutting is a major determinant of regeneration success. Those stands in which advance seedlings are abundant can generally be harvested by clearcutting, with assurance that a satisfactory new stand will develop on the area. Guides have been developed to help the forest manager evaluate advance reproduction and predict probable regeneration success *(Grisez and Peace 1973)*.

Research has also shown that shelterwood cutting techniques can be used to increase the amount of advance reproduction in stands where it is not adequate. Although there are certain stand and site conditions where shelterwood cutting should not be used, this cutting method provides a means of reproducing many Allegheny hardwood stands that would fail to regenerate satisfactorily if clearcut *(Marquis 1973; Husch 1954; Hough 1937)*.

Recent evaluations of regeneration cuttings made 30 to 40 years ago suggest that tolerant species such as sugar maple, beech, and hemlock find a place in the main crown canopy of new even-aged stands only if they have an appreciable head start on the faster growing and less tolerant species. To insure their representation in the new stand, specified numbers of saplings and small pole-size stems of these species may be retained as growing stock when the main portion of the existing stand is harvested.[1]

Although results to date are still tentative and there is additional research now under way that will probably result in further refinements, the information now available provides a far better basis for mangement than what has been available previously.

This publication is a summary of information now available about the regeneration of Allegheny hardwoods in the form of an interim guide suitable for field use. This guide covers only regeneration and applies only to stands that are ready to be harvested.

## Silvicultural Systems

A major decision to be made on any forest tract is whether it will be handled on an even-aged or uneven-aged system. This decision must be based on the management objectives for that area and on the biological restraints inherent in the ecosystem in question.

Because Allegheny hardwood forests contain many species spanning a range of tolerance levels, the choice of the silvicultural system to be used would be wide were it not for deer pressures on regeneration. Heavy browsing makes regeneration difficult to obtain under any silvicultural system, but is most restrictive under cutting techniques that require seedlings to develop where dense shade prolongs their exposure to deer (which occurs under individual-tree selection cutting) or where the deer pressure tends to be concentrated on small numbers of seedlings (as with group-selection cutting).

For this reason, uneven-aged silvicultural systems are not as useful as they might be in Allegheny hardwoods and are not recommended in this guide except for those areas where even-aged silviculture is inappropriate because of management objectives or site con-

[1] Roach, Benjamin A. Effect of residual saplings of sugar maple and beech on the species composition of new stands following harvest cutting. Unpublished office report. USDA For. Serv. Northeast. For. Exp. Stn., Warren, Pa. 1975.

ditions. These include locations where recreation, esthetics, and similar land uses are of such high importance that they preclude any cutting technique that completely removes the overstory. For areas fitting this description, skip the sections "Stand Diagnosis" and "Guides To Regeneration" that follow and refer to the section on "Uneven-Aged Silviculture" at the end of this guide.

For all other situations, including stands where esthetics and recreation may be important but do not preclude even-aged silviculture, refer to the Stand Diagnosis and Regeneration Guides that follow.

## Stand Diagnosis

Before using the reproduction key that follows, make a stand diagnosis to evaluate regeneration potential. The stand diagnosis includes the identification of stand units and evaluation of the existing overstory and understory vegetation.

Normally a stand diagnosis would be performed in the process of deciding that a particular stand is ready for harvesting. If so, collection of understory data is the only additional task required, and it can be done at the same time that overstory data are collected. The description that follows includes only those items of information needed to evaluate regeneration. Additional information may also have been required to determine what cutting, if any, was appropriate.

### Identification and Sampling of Stand Units

Stand units are usually identified first from aerial photographs and later are checked on the ground and adjusted as needed. The stand area should be small enough so that it will have reasonably similar stand and site conditions throughout, but large enough to provide efficient operation. Stand size normally falls between 10 and 50 acres, but may be larger or smaller under some conditions.

Once the stand unit has been identified, sample plots are located by using some systematic sampling scheme to insure that the plots are well distributed throughout the stand. As a general rule, one sample plot per acre will provide an adequate sample, but in no case should the number of overstory plots be fewer than 10 nor the number of understory plots fewer than 20.

### Overstory Evaluation

Information about basal area for each of two species groups, total number of trees, and mean stand diameter are needed for evaluation of overstory stocking. Basal area can be estimated by a prism count, and numbers of trees can be estimated by a tree count of a 1/20-acre (26-foot 4-inch radius) plot. All trees 0.5 inch dbh and larger should be included in both the prism count and the tree count. The same center point should be used for both counts. Mean stand diameter and stocking level can then be determined from stocking charts.

For stocking charts and how to use them, see appendix.

The two species groups on which basal area must be recorded are: (1) black cherry, white ash, and yellow-poplar; and (2) all others. A sample form showing the information needed is presented as figure 1. Additional data about the overstory are often needed for other purposes, so the actual form may differ from that shown in figure 1; but it must include the items provided here.

When all plots have been sampled, the sum and mean of the prism and tree counts are calculated. Next the proportion of basal area in black cherry, white ash, yellow-poplar and the average basal area of both species groups combined are computed; then stocking charts are used to look up mean stand diameter and stand stocking percentage. All the computations may be recorded on the tally form, as illustrated in figure 1.

### Understory Evaluation

To evaluate the understory, you need information about the stocking of advance reproduction in several species-size groups and about the stocking of undesirable competitors. Observations of soil drainage are also best made when the understory is sampled.

Figure 1.—Sample stand diagnosis tally form for regeneration.

Forest Allegheny Compartment 261

Stand 17 Date 9/74

| Plot No. | Overstory | | | Understory | | | | | Site |
|---|---|---|---|---|---|---|---|---|---|
| | Prism Count Basal Area in trees 1 inch dbh & larger | | Tree Count Trees 1 inch dbh & larger | Advance Reproduction | | Undesirable Competitors | | | poorly drained |
| | BC-WA-YP | Others | | small | large | fern | grass | beech st.maple | |
| 1 | 30 | 100 | 35 | ✓ | ✓ | ✓ | | | ✓ |
| 2 | 80 | 80 | 22 | | | | | | |
| 3 | 50 | 80 | 41 | ✓ | | | | | |
| 4 | 20 | 120 | 40 | ✓ | | | | | |
| 5 | 100 | 30 | 29 | | ✓ | | | | |
| 6 | 10 | 100 | 38 | | | ✓ | ✓ | | |
| 7 | 40 | 80 | 31 | | | | | | |
| 8 | 20 | 80 | 28 | ✓ | | | | | |
| 9 | 20 | 100 | 20 | ✓ | | | | | |
| 10 | 30 | 90 | 46 | ✓ | | | ✓ | ✓ | |
| Σ | 400 | 850 | 330 | 6 | 2 | 2 | 2 | 1 | 1 |
| $\bar{x}$ | 40 | 85 | 33 x 20 = 660 | | | | | | |
| both groups | 125 | | % of plots | 60 | 20 | 20 | 20 | 10 | 10 |
| %BC-WA-YP | 32 | | % of plots | 70 | | | | | |

Understory vegetation plots should be 6-foot-radius plots. The same plot centers should be used as for overstory evaluation. Some additional understory plots may also be needed to meet the minimum of 20 plots. Spaces for recording understory data are provided on the sample form (fig. 1).

Understory and soil-drainage information need be recorded only as a check mark or yes-no entry. However, actual numbers or coverage may be recorded if these data are desired for other purposes. At the minimum, indicate with a check mark each plot that contains:

- *Small advance reproduction.*—At least 15 black cherry stems or 80 stems of any desirable species under 0.5 inch dbh. In making this determination, do not count newly-germinated seedlings because survival is often poor during the first few months after germination.
- *Large advance reproduction.*—At least four acceptable stems of sugar maple, beech, or hemlock 1 to 2 inches dbh or at least two acceptable stems of these species 3 to 4 inches dbh, or at least one-half the above number of both size classes. Acceptable stems of these species must have reasonably straight boles and moderate crowns so that they can be expected to survive and grow into acceptable growing stock if released.
- *Grass-fern.*—At least 30 percent of the ground area is covered by a grass or sedge, or at least 30 percent is covered by hay-scented fern or New York fern. If the identity of the ferns is uncertain, count any fern that grows as individual fronds from the ground level, and ignore any ferns that grow in clumps. Because coverage of grass and ferns is usually spotty, it is best to estimate the coverage of these species on plots larger

than 6-foot-radius. The 1/20-acre plot used for the tree count is better. This estimate is an ocular one, based on the proportion of ground area covered by these plants.

- *Beech root suckers or striped maple stems.* —At least eight stems (total) of these two species.

- *Poorly drained soil.*—Plot has evidence of standing water during wet periods or soil mottling within 6 inches of the surface. As with grass and fern, evidence of soil drainage is better observed on the 1/20-acre plot than on the smaller 6-foot-radius plot.

When all plots have been sampled, compute proportions of plots with checkmarks in each category above, as shown in figure 1.

## Guides to Regeneration of Allegheny Hardwoods

Figure 2 is a flow chart from which it is possible to evaluate the regeneration potential of a stand and arrive at a prescription for treating it. Data from the stand diagnosis (fig. 1) are needed for using this chart.

For simplicity of presentation, wording in the flow chart has been kept at a minimum. More complete descriptions of the criteria at each branching point (shown in rectangles on the chart) are contained in the section entitled "Prescription Criteria", with numbers and letters keying the descriptions to the chart. More complete discussions of the regeneration prescriptions (shown in ovals on the chart) are contained in the section entitled "Regeneration Cutting Guidelines", with letters keying the discussions to the chart.

To arrive at a prescription for a particular stand, start at the top of the chart and follow the lines through the appropriate branches until you reach a prescription, referring to the following sections for detailed information as needed.

These guides are intended for use only in stands that are mature or that are at least 60 years old and ready to be harvested for some other management consideration.

### PRESCRIPTION CRITERIA

1. Soil Drainage:

   a. *Well drained.*—Less than 30 percent of the stand area has evidence of standing water during wet periods or soil mottling within 6 inches of the surface. Soil drainage is not such that it will limit silvicultural alternatives.

   b. *Poorly drained.*—More than 30 percent of the stand area has evidence of standing water during wet periods or soil mottling within 6 inches of the surface. High water tables following complete overstory removal on poorly drained soils will often interfere with regeneration and make even-aged management undesirable. The problem may be compounded if the poorly drained soil is in a valley or topographic depression where frost pockets may form *(Hough 1945)*. Water tables are kept at lower levels by evapotranspiration if overstory stocking is never reduced below the B level.[2]

2. Advance Reproduction:

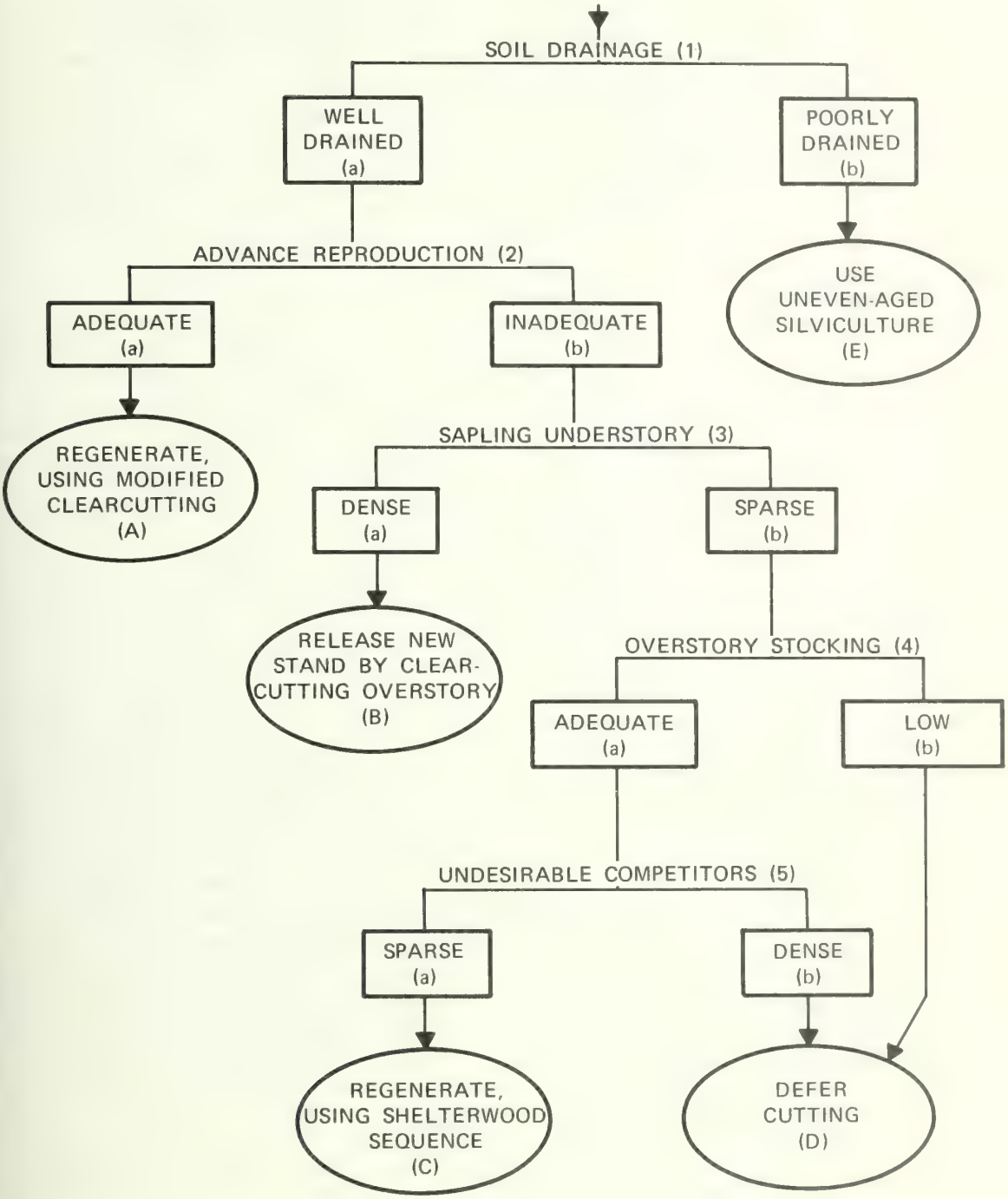
   a. *Adequate.*—At least two-thirds of the reproduction plots are stocked with small advance reproduction, or at least one-half of the plots are stocked with small reproduction, and enough additional plots are stocked with large reproduction to total at least two-thirds of the plots stocked.

      To be stocked with small advance reproduction, a 6-foot-radius plot must contain at least 15 black cherry stems or 80 stems of any desirable species less than 0.5 inch dbh. In making this determination, do not count newly germinated seedlings, because survival is often poor during the first few months after germination.

      To be stocked with large advance reproduction, a 6-foot-radius plot must

[2] Roach, Benjamin A. Interim guide to Allegheny hardwood stocking. Unpublished office report. USDA For. Serv. Northeast. For. Exp. Stn., Warren, Pa. 1975. See appendix for the stocking charts and a brief description of their use.

Figure 2.—Guides to Allegheny hardwood regeneration.



contain at least four acceptable stems of sugar maple, beech, or hemlock 1 to 2 inches dbh, or at least two acceptable stems of these species 3 to 4 inches dbh, or at least one-half of the above numbers of both sizes classes. To be acceptable, trees must have reasonably straight boles and moderate crowns so that they can be expected to survive and grow into acceptable growing stock if released.

b. *Inadequate.*—Fewer than two-thirds of the reproduction plots meet the stocking criteria listed in a. above.

3. Sapling understory:

a. *Dense.*—At least two-thirds of the reproduction plots are stocked with large advance reproduction; these stems plus small poles up to about 8 inches dbh are adequate in species composition, number, and quality to form a new stand composed of these stems alone. Stands that meet these criteria are two-aged stands resulting from heavy partial cuttings during the past 20 years or so. The overstory is usually sparse.

b. *Sparse.*—Fewer than two-thirds of the plots are stocked with large advance reproduction; or species composition, number, and quality of these saplings plus small poles up to 8 inches dbh are inadequate to form a new stand.

4. Overstory Stocking:

a. *Adequate.*—Stocking level of overstory trees 0.5 inch dbh and larger, as determined from stocking charts in the appendix, is 80 percent of A level or higher.[2]

Overstory stocking may also be considered adequate if it is between 70 and 80 percent of A level and the low density is due to some recent reduction such as insect or disease outbreak, ice damage, or windthrow.

b. *Low.*—Stocking level of overstory is less than prescribed above.

If the stand has been below normal in stocking for some time and still has poor advance reproduction, it is doubtful that further reduction in stocking will rectify the problem. Furthermore, the low stocking will make it difficult to get an operable cut without reducing the overstory density too much. In such cases, shelterwood cutting should not be attempted.

5. Undesirable Competitors

a. *Dense.*—Thirty percent or more of the reproduction plots are heavily stocked with grass, or 30 percent or more are stocked with ferns, or 30 percent or more are stocked with either beech root suckers or striped maple stems.

To be heavily stocked with grass or ferns, a plot of any size must have at least 30 percent of the ground area covered by any grass or sedge, hay-scented fern, or New York fern. If the identities of the ferns are uncertain, count any fern that grows as individual fronds from the ground level, and ignore any ferns that grow in clumps.

To be heavily stocked with beech root suckers or striped maple stems, a 6-foot-radius plot must contain at least eight stems (total) of the two species.

The stocking levels prescribed here for undesirable competitors is based on preliminary research findings and may be modified substantially as better information becomes available on the extent to which these species interfere with desirable regeneration. However, it is known that partial cutting will greatly stimulate these competitors where they are sufficiently dense before cutting.

b. *Sparse.*—Less than 30 percent of the reproduction plots are heavily stocked with grasses, ferns, beech root suckers, or striped maple stems as prescribed above.

# Regeneration Cutting Guidelines

## EVEN-AGED GUIDELINES

The type and number of cuttings required to regenerate new even-aged stands of Allegheny hardwoods will depend upon the amount of advance regeneration present before cutting and the relative importance of recreation and esthetic uses of the stand in question.

If advance regeneration is sparse in well-stocked stands, a shelterwood cutting sequence is appropriate. First, a seed cutting is made to open up enough growing space to encourage the establishment of new seedlings. This is followed in 5 to 10 years by a removal cutting to harvest the remaining overstory and release the newly established seedlings.

If advance regeneration is abundant, the seed cutting is not needed; and the overstory may be removed by clearcutting.

The unsightly initial appearance of a one-cut removal (either clearcutting or shelterwood removal cutting) may be improved by spreading the removal over two cuttings. In this way, reproduction has time to grow large enough to cover slash, stumps, and soil disturbance before all of the overstory is gone. This technique has not been thoroughly tested, but it warrants consideration in areas where esthetics and recreation are comparable in importance to timber production.

### Clearcutting (A)

To insure successful reproduction, clearcutting or any other overstory removal cutting should be done only in stands where the advance regeneration is abundant (meets the stocking criteria previously described). The numbers of advance seedlings required may appear to be large, but this is because browsing by deer will destroy many of them before they can develop into sapling size. The impact of deer on regeneration is probably more severe in Allegheny hardwoods than in any other eastern forest type.

In areas where timber production is the primary goal of management, the overstory is generally removed in a single operation or clearcutting. All trees, including culls and nonmerchantable trees, should be removed or killed so that they do not interfere with the developing reproduction. However, up to 100 stems per acre of 2- to 6-inch diameter sugar maple, beech, and hemlock of acceptable quality may be retained to insure representation of these species in the next stand.

### Two Removal Cuts for Esthetics

In areas where esthetics are important, but where timber production is still a primary goal of management, the removal may optionally be spread over two separate cuttings.

When two removal cuttings are used, the first one should reduce stocking to 30 percent of the A level,[2] with the residual made up of uniformly spaced individuals of the most vigorous, most desirable, and most windfirm stems. This cutting will provide a considerable increase in light and moisture for the already established seedlings, permitting them to begin rapid height growth.

The remaining overstory should then be completely removed about 5 years later, by which time some of the new seedlings should be 5 feet high or taller. In this way, stumps, slash, and logging disturbance will be at least partially hidden by the large reproduction before all overstory is removed; and the site will at no time be devoid of protective vegetation. Of course, the additional entry to the area will produce some increase in costs of management, and extra care may be required to insure that excessive amounts of reproduction are not destroyed by skidding during the second operation.

### Distribution and Layout of Reproduction Cutting Areas

Forest yield regulation under even-aged management is achieved primarily by scheduling the cutting of the harvest-regeneration areas. To provide a sustained yield and an even flow of timber products, areas to be cut must be scheduled carefully to create and maintain the desired age-class distribution over the compartment, working circle, or forest area. Thus in scheduling regeneration areas, you must consider not only the condition of the stand in question but also the distribution of age classes, volumes, and stand

conditions in the surrounding stands. Furthermore, wildlife and esthetics are affected by the distribution of cutting areas. For a more complete discussion of this subject, the reader is referred to a paper by Roach *(1974)*.

Visual appearances of new harvest-cut areas can be improved if certain established procedures are followed such as: limitation of opening size to a maximum of about 50 acres; avoidance of new openings immediately adjacent to ones of the previous cutting cycle, avoidance of geometric shapes in the outline of the openings; care in the location of roads; and use of measures to reduce the height of slash piles and other logging debris. However, slash piles protect seedlings from deer browsing *(Grisez 1960)* and should not be removed from the site.

Detrimental effects sometimes attributed to clearcutting can also be avoided if certain established procedures are followed. Erosion and sedimentation of streams is avoided if temporary roads are carefully laid out and then water-barred or seeded with grasses after logging is complete. Avoidance of skidding during wet periods is also important. Further protection against sedimentation and increased stream temperatures can be achieved by leaving strips of vegetation 50 to 100 feet wide on each side of all permanent watercourses.

### Release Cutting (B)

In stands that have developed a dense sapling and small pole understory, removal of the remaining overstory is all that may be needed to obtain a new stand. This will release the saplings and small poles so that they can develop fully.

Stands appropriate to release cuttings are usually two-aged stands that have resulted from heavy cutting (heavier than normal thinnings) during the past 10 to 20 years. Often the overstory is sparse and may be of poor quality, depending on the nature of the previous cutting. The understory, too, is often of less-than-ideal composition. Thus, the appropriate silviculture for such stands must be decided on an individual basis.

The merits of retaining and working with the existing overstory must be weighed against liquidation of the overstory and working with the understory. In either case, it should be recognized that new seedling regeneration will be extremely difficult to establish in such stands and that the choice is among the age classes already present on the site.

### Shelterwood Cutting (C)

A shelterwood cutting sequence appropriate in Allegheny hardwoods involves a seed cutting followed by one or two removal cuttings.

#### Seed Cutting

The major goal of the seed cutting is to reduce canopy density uniformly to create optimum environmental conditions for seedling establishment. The seed cutting should reduce the overstory to 60 percent of A-level stocking, as determined from the stocking charts (appendix).[2]

In addition to providing shelter for the establishment of new seedlings, the residual overstory serves as a source of seed. Thus it is important to retain the larger and more desirable stems until the final harvest. Valuable species that are poorly represented in the stand should receive special consideration for retention.

Trees removed during the seed cutting should be distributed uniformly throughout the stands. Cutting of groups of trees that would create large canopy holes should be avoided. Insofar as possible, the trees removed should also be the least desirable in the stand and should generally come from the lower crown classes. Thus culls, poorly formed individuals, and less desirable species should be removed first—especially in the smaller size classes—along with a few better individuals and larger stems where removal is required to achieve relatively uniform canopy opening.

Additional purposes of this cut, like that of any thinning under even-aged management, is to provide the best stems and best species in the stand with adequate growing space to maximize value increase and seed production before the final harvest. It should also tend to concentrate trees in a narrower range of diameters.

If it is desired, small, unmerchantable trees that would normally be killed after the final removal cutting can also be removed during the seed cutting.

In laying out actual cutting boundaries, remember that shelterwood cutting will eventually result in complete overstory removal. Distribution of cutting areas for wildlife, control of their size and shape, and blending of the eventual opening with surroundings must be considered at the time of the seed cutting. (See section on "Distribution and Layout of Reproduction Cutting Areas", under "Clearcutting".)

#### Removal Cutting

In most shelterwood situations, a single removal cutting will normally be made 5 to 10 years after the seed cutting to harvest the remaining overstory and release the now-established reproduction. In areas where esthetics are more important, the removal may optionally be spread over two separate cuttings. (See section on "Two Removal Cuts for Esthetics", under "Clearcutting".)

In all cases, timing is dependent upon the establishment of new seedlings and should be made only if advance regeneration stocking levels meet the guides described previously. If reproduction does not meet these guides, removal cutting should be deferred.

All trees, including culls and nonmerchantable stems 2 inches dbh or larger, should be removed so that they do not interfere with the developing reproduction. However, up to 100 stems per acre of 2- to 6-inch diameter sugar maple, beech, and hemlock of acceptable quality may be retained to insure representation of these species in the next stand.

### Deferred Cutting (D)

In this guide to regeneration of Allegheny hardwoods, we recognize two situations where satisfactory regeneration may not be obtainable with any of the cutting techniques available.

In stands lacking adequate advance reproduction, and where overstory stocking is below 70 to 80 percent, neither clearcutting nor shelterwood cutting are likely to be successful. There are not enough advance seedlings to expect good results from clearcutting, and shelterwood cutting will probably not stimulate new seedlings because the overstory density is already low enough for advance seedlings to have developed if some other factor were not limiting. In such situations, it is recommended that cutting be deferred until more information is available on the treatment of such stands, or that other special measures such as artificial regeneration and protection from deer be considered.

In stands lacking adequate advance reproduction and containing dense coverage of grasses or ferns or numerous beech root suckers or striped maple stems, shelterwood cutting may stimulate these competing plants to the point where they interfere with desired reproduction. The nature and extent of the competition offered by these plants have not been fully evaluated, but there are numerous examples of regeneration failure that can be attributed to them. Until more detailed information is available, we recommend that shelterwood cutting be deferred in stands containing these plants in amounts exceeding the limits previously specified.

Where beech or striped maple are the problem, a possible alternative is to kill these stems by mistblowing herbicides *(Smith and Trimble 1970)* before shelterwood cutting. However, such treatments are not effective on grasses or ferns and have not been tested in the Allegheny hardwood type. Such a treatment would kill any desirable advance reproduction present, and a whole new crop of advance seedlings would have to be developed before the removal cutting. Thus attempts to eliminate beech and striped maple in this way should be limited to stands where the need for cutting is urgent, where grasses and ferns are not a problem, and where no other alternative is available.

## UNEVEN-AGED GUIDELINES (E)

Both individual-tree selection and group-selection cutting methods may be useful in Allegheny hardwoods, particularly on small ownerships or on portions of large ownerships where recreation and esthetics are especially

important. Although considerable information is available from other northern hardwood regions, guidelines are not available for the Allegheny Plateau where deer browsing limits reproduction.

Individual-tree selection cutting in any northern hardwood type will tend to favor the tolerant species such as beech, hemlock, and sugar maple, and discriminate against less tolerant species. In the Allegheny hardwood type, deer browsing further alters species composition. Hemlock and sugar maple are heavily browsed, and beech is sometimes used less *(Hough 1965)*. Thus individual-tree selection cutting where deer browsing is heavy will tend to produce stands primarily of beech or, in some instances, may interfere with development of any species of reproduction *(Richards and Farnsworth 1971)*.

Similar problems may occur in the small openings of group-selection cutting. Reproduction in early strip and patch cuttings on the Allegheny Plateau was often completely destroyed by deer.

Because of the lack of information and the potential damage to reproduction, use of uneven-aged silviculture should be considered experimental and should be limited to those stands or properties where even-aged silviculture is not appropriate.

Nevertheless, these cutting methods offer many potential advantages for small properties and areas where esthetics and recreation are especially important, and they deserve to be tried in such situations. Results of such trials should be observed carefully.

### Individual Tree Selection Cutting

As a general guide, individual-tree selection cutting should reduce stand stocking to the B level.[2] In selecting trees to remove, deliberate attempts must be made to cut trees in all diameter classes to develop and maintain a balanced stand structure. Unless this is done, gaps and surpluses will occur in the diameter distribution, which will eventually lead to alternating periods of low and high yield rather than sustained even-flow yields. The approximate diameter distribution to be maintained should be:

| *Diameter group (inches dbh)* | *Residual basal area (percent)* |
|---|---|
| 1-5 | 14 |
| 6-10 | 32 |
| 11-16 | 32 |
| 17+ | 22 |

Cuttings may be made every 10 to 20 years, but the actual interval depends on the time required for the stand to return to within 80 to 90 percent of A-level stocking.

*Group-selection cuttings* may also be useful where small openings are desired to create diversity of appearance or habitat or to increase the proportions of the less-tolerant species in the reproduction. To maintain the desired visual effects, group-selection openings should usually not be larger than a few acres and may be as small as about 1/3 acre. Individual-tree selection cuttings should also be made in the area between openings.

If less-tolerant reproduction is obtained in group-selection openings, its growth and survival are enhanced if the openings are enlarged during subsequent cutting cycles to maintain adequate light exposure. Enlargement of the openings on all sides is not necessary; best results are obtained if the enlargement is made on the southern edge of the established reproduction. Considerable planning is required to fit the new cuttings into the mosaic of previous ones; this should be done at the time of the initial cuttings where possible.

The regulation of cut and yield can be difficult under group-selection cutting. Volume control is extremely difficult because there is no way to regulate size distribution of the residual stand. The small size (and therefore large number) of the openings required make area control extremely difficult on large properties, but it can be achieved on smaller ones.

# Appendix

## STOCKING CHARTS FOR ALLEGHENY HARDWOODS

Adapted from Roach[2]

The two charts that follow permit the evaluation of stocking level for stands of Allegheny hardwoods. To use these charts, you must have data on: numbers of trees per acre 0.5 inch dbh and larger, total basal area per acre in trees 0.5 inch dbh and larger, and proportion of the total basal area represented by black cherry, white ash, and yellow-poplar. See section on "Overstory Evaluation" for further details on data needed.

The two charts are similar. The first is for stands 3 to 10 inches in diameter; the second is for stands 6 to 15 inches in diameter. Average diameter is the diameter of the tree of average basal area.

Each chart contains two series of lines. The "A" lines represent 100 percent or full stocking for stands containing the proportions of black cherry, white ash, and yellow-poplar shown. These are the levels of stocking that all stands will tend to approach if they are left undisturbed for a sufficiently long period of time.

The "B" lines represent 60 percent of full stocking. At B level, the individual trees in the stand have considerable growing space, but there are still enough trees to fully occupy the site. Total stand growth is about the same as at A level stocking, but this growth is being put on fewer trees. At densities below B level, individual trees may grow a little faster because they have even more growing space, but there will be too few trees to fully occupy the site, so total stand growth will be sacrificed. In thinnings, stand density is normally reduced to the B level. We also recommend this level for the seed cut of a shelterwood sequence.

An example will illustrate proper use of the charts. Consider a stand that has 300 trees per acre and 145 square feet of basal area, of which 72.5 square feet (or 50 percent) is in black cherry, white ash, and yellow-poplar.

Find the point in the chart where the line for 300 trees intersects the line for 145 square feet, and note where this point falls in relation to the A-level percent composition curves. This stand would be 100-percent stocked if it contained 30 percent black cherry, white ash, and yellow-poplar instead of 50 percent. Also note where the point of intersection falls in relation to the diagonal lines representing average diameter. It falls between the 9-inch and 10-inch lines; we can interpolate here and estimate that this stand has an average diameter of 9.4 inches.

Now, imagine that there is a line representing 9.4 inches: follow that line upward on the chart to the point where it would intersect the A-level 50-percent cherry-ash-poplar line. Note that this point corresponds to a basal area of about 159 square feet. This is the basal area we would expect of a fully stocked stand of the same average diameter and containing the same proportion of cherry, ash, and poplar as our sample stand. Since our sample actually contains only 145 square feet of basal area, it is 91 percent (145/159) stocked.

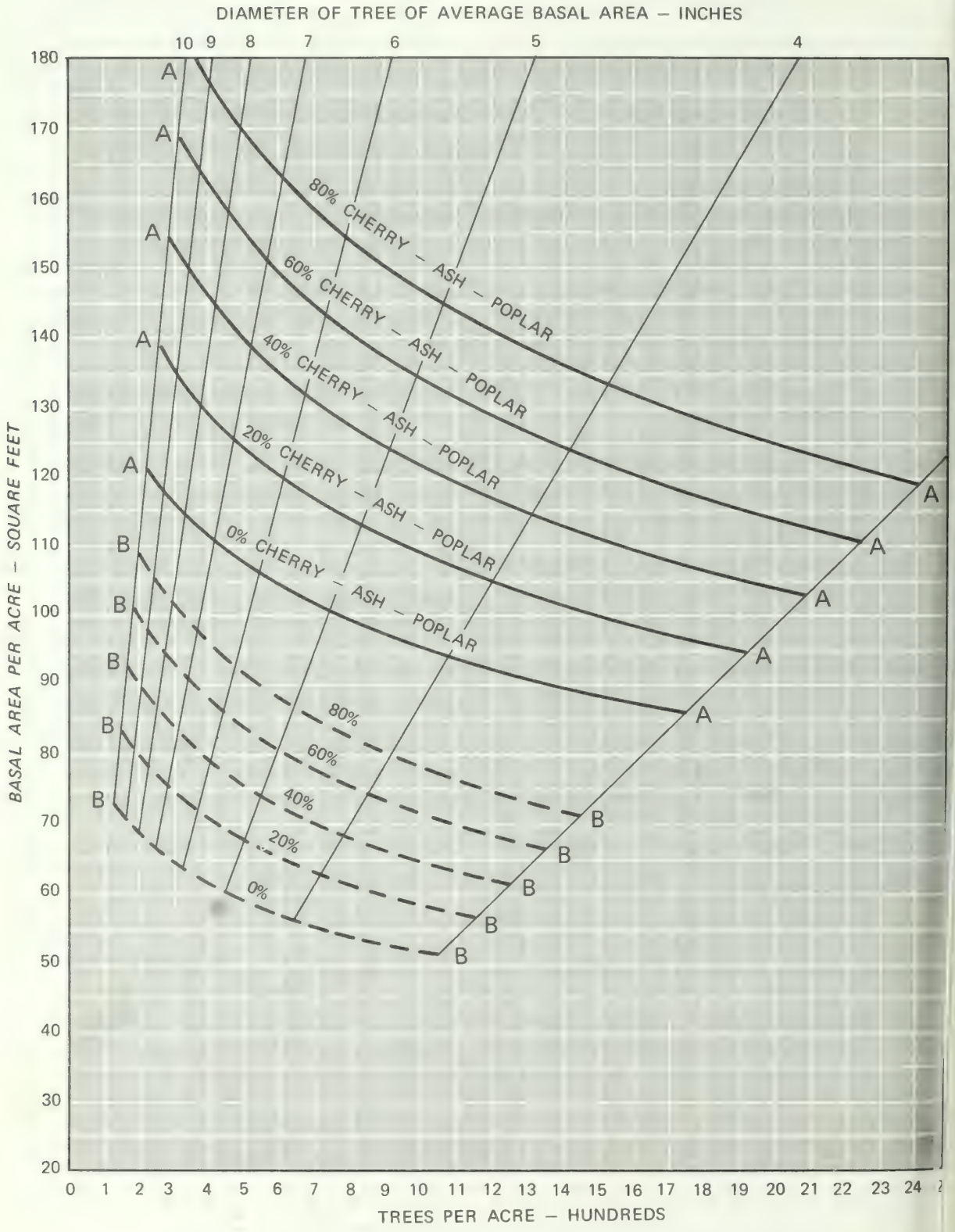
B-level stocking for the sample stand can be determined in the same manner. Follow the 9.4-inch diagonal line downward in the chart to the point where it would intersect the B-level 50-percent cherry-ash-poplar line. Note that this corresponds to a basal area of about 95 square feet. This is the minimum basal area that should be left after thinning or shelterwood cutting, *provided* that the species composition and average stand diameter are not altered by the cutting.

Caution must be exercised here, however, because species composition and average stand diameter are usually altered by cutting. If trees removed are from the smaller sizes, as recommended in the shelterwood cutting guidelines, mean stand diameter will be increased by the cutting. Experience has shown that this increase is often about ½ inch for each 10 percent of the stocking removed. Likewise, the valuable black cherry, white ash, and yellow-poplar are usually favored, so the proportion of these species may be increased by cutting. Both changes increase the amount of basal area required for minimum (B-level) stocking.

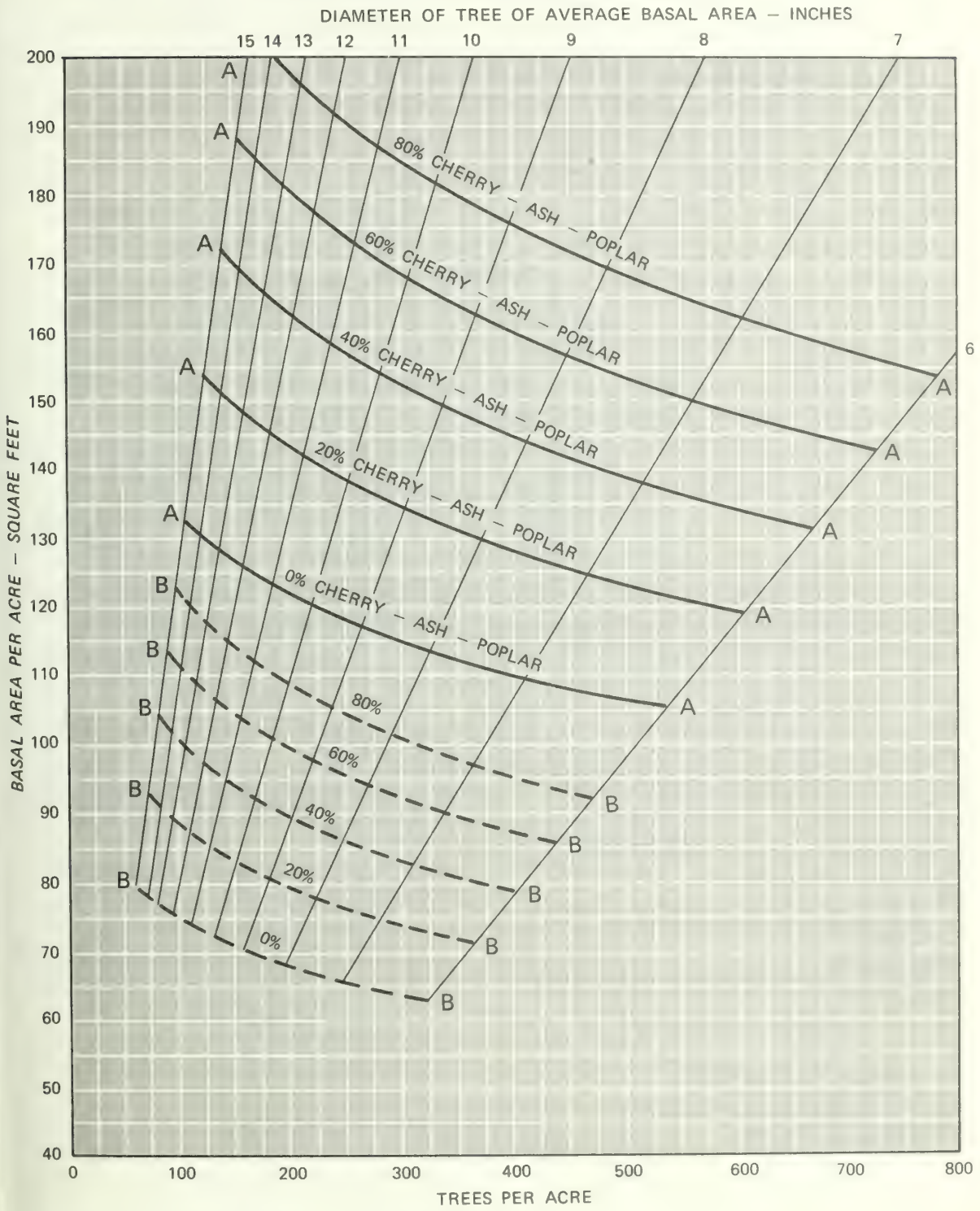
STOCKING GUIDE FOR ALLEGHENY HARDWOODS

1.

FOR STANDS 3 TO 10 INCHES IN DIAMETER



## STOCKING GUIDE FOR ALLEGHENY HARDWOODS
## 2.
## FOR STANDS 6 TO 15 INCHES IN DIAMETER



Using our example above, and assuming no change in species composition or mean stand diameter, we would normally prescribe that cutting remove 50 square feet of basal area to reduce density from the existing 145 square feet (91-percent stocking) down to the B level of 95 square feet (60-percent stocking). However, if cutting increases average diameter by ½ inch for each 10 percent of stocking removed, the residual stand would have a mean diameter of about 11 inches. B level for an 11-inch diameter stand with 50 percent cherry-ash-poplar is 100 square feet of basal area. So the cutting should actually remove 45 square feet of basal area—rather than the 50 square feet originally calculated. To avoid overcutting in actual situations, possible changes in both diameter and species composition must be considered.

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Regeneration of Allegheny hardwoods is difficult to obtain because of excessive deer browsing on tree seedlings. Density of advance seedlings, density of competing plants, soil drainage, and the importance of esthetic and recreation uses affect the choice of silvicultural system and cutting procedure for obtaining satisfactory regeneration. In this paper, we provide guides needed for evaluating the regeneration potential and prescribing the most appropriate treatment for cherry-maple stands on the Allegheny Plateau of Pennsylvania and New York.

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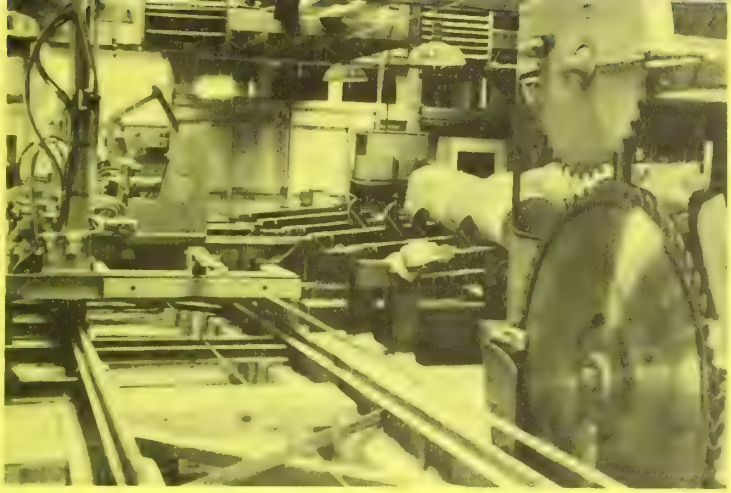
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# How to Predict Lumber-Grade Yields for Graded Trees






USDA FOREST SERVICE GENERAL TECHNICAL REPORT NE-20
1976

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

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MANUSCRIPT RECEIVED FOR PUBLICATION 8 SEPTEMBER 1975

## INTERESTED?

If you are interested in developing lumber-grade yields for your sawmill, and have questions about field procedure or analysis, please contact Project 3102, Northeastern Forest Experiment Station, P.O. Box 365, Delaware, Ohio 43015.

# How to Predict Lumber-Grade Yields for Graded Trees


## ABSTRACT

A procedure is shown for developing lumber-grade yields to be used with the USDA Forest Service Hardwood Tree Grades for Factory Lumber. Yield development is followed from the time of selecting trees, through sawing the logs and grading the lumber, to the development of predicted lumber grade yields. By following this procedure, a sawmill operator can develop yields that are representative of both his sawmill and the local timber.

IN OUR RESEARCH with hardwood tree grades, we have developed a procedure that the sawmill owner can use to develop lumber-grade yields for his own sawmill. This procedure may also be useful to consulting foresters and state and federal utilization specialists.

Hardwood tree grades and lumber-grade yields are now available for 11 species: yellow birch, paper birch, sugar maple, red maple, yellow-poplar, basswood, black cherry, northern red oak, black oak, white oak, and chestnut oak (*Hanks 1976b*).

In our field trials of the USDA Forest Service Hardwood Tree Grades for Factory Lumber, we have shown that the tree grades can be used to separate groups of trees into grades that have meaningful value differences (*Hanks 1976a*). These trials also showed that total tree lumber volume and value can be predicted by using the lumber-grade yields.

For groups of about 50 trees, the differences between actual and predicted lumber volumes generally ranged from 2 to 9 percent, while differences for lumber value generally ranged from 2 to 14 percent. These differences occurred because volume and value-controlling factors such as tree form and interior cull are not consistent within a species. Sawmill equipment, sawing practices, and markets also affected the volume and value of lumber produced during the field trials and during the studies conducted when the lumber-grade yields were being developed.

To lessen the effects of variation due to sawmill practices and the nature of the timber sawed, a sawmill operator can determine lumber-grade yields specific to his mill and the timber he handles. He may also want to determine yields and values of species for which yield information is unavailable.

This guide outlines a procedure for developing lumber-grade yields to be used with the existing hardwood tree grades.

If an operator is not interested in lumber-grade yields, but needs to know only total value and volume of lumber expected from graded trees, we have a procedure that he can use.

To make full use of this guide, a sawmill operator must deal with standing trees that are graded. Access to data-processing equipment, including a computer, is assumed.

## Development of Lumber-grade Yields

### Field Procedure

The first step is to establish the available range in dbh (diameter at breast height) and merchantable height. This information could come from recent inventory or appraisal records.

Then, for the species involved, select *approximately 60 trees per tree grade* that cover the established range in sizes. When choosing trees, it is best to eliminate non-typical trees—trees that fork, trees that are outside the range of sizes normally encountered, and trees that have excessive defect outside the grading section. Of course, such trees do exist, and at a later time you will be required to appraise them. For further discussion of this, see the appendix.

At the time of tree selection, measure both dbh and merchantable height. Record dbh to the nearest inch and merchantable height to the nearest foot. Also record tree grade, and assign a number to each tree (fig. 1).

After felling, the trees should be bucked, and each log should be numbered for future identification. We suggest that the number be composed of the tree number followed by the log position within the tree; for example, the second log from the fifth tree would be tree-log No. 05-2 (fig. 2). Study logs should be decked together on the mill yard in preparation for sawing (fig. 3).

Species _____ Date _____

Comments: _____ Recorder _____

| TREE NUMBER | D.B.H. | MERCHANTABLE HEIGHT | TREE GRADE | TREE NUMBER | D.B.H. | MERCHANTABLE HEIGHT | TREE GRADE |
|---|---|---|---|---|---|---|---|
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Figure 1.—Suggested form for recording tree information.

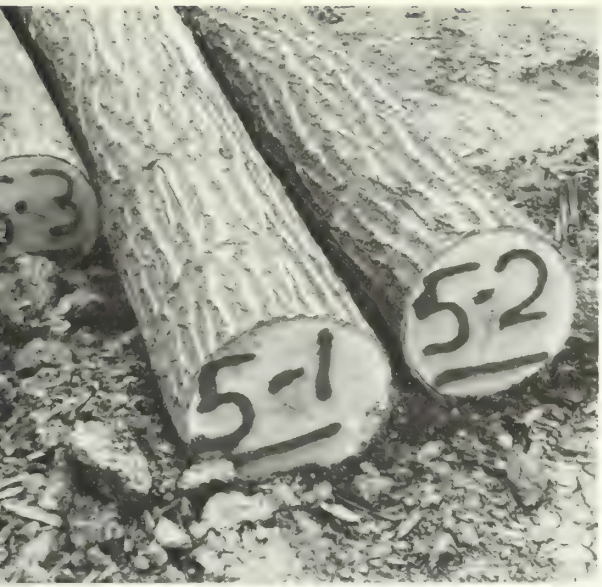



Figure 2.—Logs from tree number 5.




Figure 3.—Study logs decked before sawing.

## Mill Procedure

The sawmill equipment should be put in top-notch condition before sawing, and the study crew should be carefully instructed as to their assignments. The lumber thickness pattern and both edging and trimming practices should be comparable with what is considered normal for the sawmill.

Our suggested numbering procedure is to assign consecutive numbers to the logs as they are sawed. The first log sawed becomes log number 1, the second log becomes log number 2, etc. These so-called sawing-order numbers differ from the previously assigned tree-log numbers. Therefore, a person should be stationed near the log deck to record the tree-log number and the sawing-order number of each log (figs. 4 and 5).

Each board from a log must be numbered with the sawing-order number (fig. 6). In other words, every board from the first log sawed must contain the number 1, etc. We have learned that, with a sequential numbering system, the numbering crew is less likely to make mistakes.

The mill layout and sawing procedure determine how many people are required for numbering boards. Any time a board is cut in two, someone must number the unnumbered piece. A typical situation will be one or two men for both the edger and trim saws and one or two men for the unedged boards. They all must know what number to apply to an unnumbered board passing their stations. The man at the trim saw can usually obtain the correct number from an adjoining piece (fig. 7), while men at the other positions can often read the sawing-order number from the end of the log (applied with chalk just before sawing). If these men cannot see the log, some sort of communication must be arranged between them and the area near the headsaw. Hand signals, blackboard, and flip cards have been used successfully. Color codes have been used in mills that do not make use of a resaw.

If a resaw is used, and cants are allowed to accumulate, special care must be taken to assure proper numbering of each board.

Black lumber keel is recommended for numbering boards.

## Lumber Grading Procedure

If the sawmill operator is interested in green lumber grade yields, the lumber should be measured and graded as soon as possible. Grading on the green chain will probably not be satisfactory because the noise levels are

Species _____ Date _____

Mill _____ Recorder _____

| SAWING ORDER NUMBER | TREE LOG NUMBER | SAWING ORDER NUMBER | TREE LOG NUMBER | SAWING ORDER NUMBER | TREE LOG NUMBER |
|---|---|---|---|---|---|
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Figure 4.—Suggested form for recording sawing sequence of tree-log numbers.



Figure 5.—Study logs being checked for tree-log number.



Figure 7.—Board numbering at trim saw.



Figure 6.—Board numbering at edger saw.



Figure 8.—Study lumber being graded and tallied.

Species _____ Date _____

Green _____ Dry _____ Recorder _____

GRADED LUMBER TALLY

| SAWING ORDER NUMBER c.c. 1-3 | LUMBER GRADE | | THICK-NESS c.c. 5-6 | SURFACE MEASURE c.c. 7-8 |
|---|---|---|---|---|
| | ACTUAL | CODE c.c. 4 | | |
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| LUMBER GRADE CODES | |
|---|---|
| 1 | FAS |
| 2 | FAS1F |
| 3 | SELECT |
| 4 | SAPS |
| 5 | 1C |
| 6 | 2C |
| 7 | SW |
| 8 | 3A |
| 9 | 3B |

Figure 9.—Suggested form for recording graded board information.

often high, and tallying does not usually proceed as fast as sawing. Somewhere in the drying yard or a nearby shed will be satisfactory (fig. 8).

If dry lumber grade yields are desired, study lumber should be properly stacked for air- or kiln-drying, and tight control should be maintained so that all boards are available for dry grading.

As the lumber is being measured and graded, the sawing-order number, previously placed on the board, must be read and tallied along with the board's thickness, surface measure, and lumber grade. A suggested tally sheet is shown in figure 9.

### Analytical Procedure

For the initial step in this procedure, a card should be punched for each board. If the board information is recorded on the suggested tally sheets, cards may be punched from them after editing for readability and completeness. Each board card must contain the sawing-order number and the grade, thickness, and surface measure of the board.

A computer program should be written that will read a board card, determine the tree-log number, compute the volume of each board, and sum the volume by lumber grade for each tree. This lumber-grade volume information, along with each tree's number, grade, dbh, and merchantable height, can then be punched onto tree cards. It may also be desirable to include total lumber volume for the tree and a code for species.

With the complete tree information available, a prediction equation can be computed for each combination of tree grade and lumber grade. An equation with the following form has proved satisfactory in the past:

Lumber-grade yield $= a + b\ (dbh)^2 + c$ (merchantable height) $+ d\ (dbh^2 \times$ merchantable height)

Predicted lumber-grade yields are obtained by using the regression coefficients with various combinations of dbh and merchantable height. These yields, when brought together, result in a lumber-grade yield table for a species and tree grade (table 1).

## Development of Total Lumber Volume and Value Predictions

A sawmill operator may be interested in predicting only total volume and value of lumber that can be produced from standing trees, and not lumber-grade yields. If so, the field procedure is comparable to that presented earlier, with one exception: *only 30 trees per grade are required.*

The mill and lumber-grading procedures and the analytical procedure through punching of board cards are the same as outlined above. After the board cards are punched, they are used with a program that computes total lumber volume and value for each tree and creates a card for each tree that contains this information, along with the tree's number, grade, dbh, and merchantable height in feet. To compute value, a schedule of lumber prices

Table 1.—Lumber-grade yield for yellow birch [In board feet]

| Dbh (inches) | Tree grade 3, 2½-Logs | | | | | | |
|---|---|---|---|---|---|---|---|
| | FAS | FASIF | Selects | No. 1C | No. 2C | No. 3A | No. 3B |
| 12 | 0.4 | 2.1 | 1.6 | 17.9 | 41.2 | 36.3 | 28.8 |
| 13 | .6 | 3.0 | 1.7 | 22.7 | 45.3 | 37.4 | 29.6 |
| 14 | .9 | 4.0 | 1.7 | 27.9 | 49.6 | 38.5 | 30.6 |
| 15 | 1.2 | 5.1 | 1.8 | 33.4 | 54.3 | 39.8 | 31.5 |
| 16 | 1.5 | 6.2 | 1.9 | 39.4 | 59.4 | 41.1 | 32.6 |
| 17 | 1.8 | 7.4 | 2.0 | 45.7 | 64.7 | 42.6 | 33.7 |
| 18 | 2.2 | 8.7 | 2.0 | 52.4 | 70.4 | 44.1 | 34.9 |
| 19 | 2.6 | 10.0 | 2.1 | 59.5 | 76.4 | 45.7 | 36.1 |
| 20 | 3.0 | 11.5 | 2.2 | 67.0 | 82.7 | 47.4 | 37.5 |
| 21 | 3.4 | 12.9 | 2.3 | 74.9 | 89.3 | 49.2 | 38.8 |
| 22 | 3.8 | 14.5 | 2.4 | 83.2 | 96.3 | 51.0 | 40.3 |
| 23 | 4.3 | 16.2 | 2.5 | 91.8 | 103.6 | 53.0 | 41.8 |
| 24 | 4.7 | 17.9 | 2.6 | 100.8 | 111.2 | 55.0 | 43.4 |

by lumber grade and thickness must be developed. By applying the appropriate price to each board card, value of the boards is obtained; and when it is summed by tree, value of the lumber in each tree can be punched onto the tree cards.

Prediction equations using total lumber volume and total lumber value as dependent variables can be computed for each tree grade. The independent variables are the same ones used earlier: $dbh^2$, merchantable height, and $dbh^2 \times$ merchantable height.

Regression coefficients derived for the total-lumber-value equations are relevant as long as the price schedule remains unchanged. When lumber prices change, tree values should be updated and a new value equation should be computed for each tree grade.

## Literature Cited


Hanks, Leland F.
1976a. Field trials of the Forest Service hardwood tree grades. For. Prod. Jour. [in press].

Hanks, Leland F.
1976b. Hardwood tree grades for factory lumber. USDA For. Serv. Res. Pap. NE-333. 81 p.

Vaughan, C. L., A. C. Wollin, K. A. McDonald, and E. H. Bulgrin.
1966. Hardwood log grades for standard lumber. USDA For. Serv. Res. Pap. FPL-63. 52 p. For. Prod. Lab., Madison, Wis.

# Appendix

## How to Estimate Lumber-Grade Volumes for Non-Typical Trees

We stated earlier that non-typical trees should not be used for developing prediction equations. However, such trees do exist, and a procedure should be established for predicting their lumber volumes and values when they are encountered during an appraisal.

For trees that fork, it is common practice to assume that merchantable height extends from the ground to the top of the longest fork. This length will be less than the total bucked-log length; but when it is used in the prediction equations, the estimated lumber volumes will compare favorably with what is actually sawed.

When trees are encountered that have diameters larger than those found in the original sample, we suggest the following:

1. Refer to HARDWOOD TREE GRADES FOR FACTORY LUMBER (*Hanks 1975*), to see if yields for the species and size class in question are available. If so, use them.

2. If published tree yields are not available, estimate grade and volume on a log-by-log basis, using log-grade yields that include large logs (*Vaughan and others 1966*).

3. If neither of the above is possible, the operator can extend the yield equations for his mill to include the trees in question. Careful checking is required to assure that these yields are realistic.

For trees that have excessive defect above or below the grading section, we suggest that lumber-grade volumes and values be reduced by an amount equal to the percentage of defect in the merchantable portion of the tree. *Excessive* is difficult to define, but we suggest that, anytime a length of 8 feet or more within the merchantable length must be culled, the volume within this section should be expressed as a percentage of the total volume, and lumber-grade volumes should be reduced accordingly. Table 2 will prove useful for estimating the percentage of tree volume contained in various portions of hardwood trees.

Table 2.—Distribution of volume within sawlog portion of trees [In percent]

| Length of piece (feet) | Tree segment, in feet | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-4 | 4-8 | 8-12 | 12-16 | 16-20 | 20-24 | 24-28 | 28-32 | 32-36 | 36-40 | 40-44 | 44-48 | 48-52 | 52-56 | 56-60 | 60-64 |
| 16 | 29 | 26 | 24 | 21 | — | — | — | — | — | — | — | — | — | — | — | — |
| 20 | 24 | 22 | 20 | 18 | 16 | — | — | — | — | — | — | — | — | — | — | — |
| 24 | 19 | 18 | 16 | 16 | 16 | 15 | — | — | — | — | — | — | — | — | — | — |
| 28 | 17 | 16 | 15 | 14 | 14 | 12 | 11 | — | — | — | — | — | — | — | — | — |
| 32 | 15 | 14 | 13 | 12 | 12 | 12 | 11 | 10 | — | — | — | — | — | — | — | — |
| 36 | 14 | 13 | 12 | 12 | 11 | 11 | 10 | 9 | 8 | — | — | — | — | — | — | — |
| 40 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 8 | 8 | — | — | — | — | — | — |
| 44 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 6 | — | — | — | — | — |
| 48 | 12 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 8 | 7 | 6 | 5 | — | — | — | — |
| 52 | 11 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 7 | 6 | 6 | 5 | 4 | — | — | — |
| 56 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 7 | 7 | 6 | 6 | 5 | 4 | 3 | — | — |
| 60 | 10 | 9 | 9 | 9 | 8 | 8 | 7 | 7 | 7 | 6 | 6 | 5 | 4 | 3 | 3 | — |
| 64 | 9 | 9 | 9 | 8 | 8 | 7 | 7 | 7 | 7 | 6 | 5 | 5 | 4 | 4 | 3 | 3 |

Headquarters of the Northeastern Forest Experiment Station are in Upper Darby, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Pennington, New Jersey.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- Warren, Pennsylvania.

Hanks, Leland F.
1976. **How to predict lumber-grade yields for graded trees.** Northeast. For. Exp. Stn., Upper Darby, Pa.
9 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-20)

A procedure is shown for developing lumber-grade yields to be used with the USDA Forest Service Hardwood Tree Grades for Factory Lumber. Yield development is followed from the time of selecting trees, through sawing the logs and grading the lumber, to the development of predicted lumber grade yields. By following this procedure, a sawmill operator can develop yields that are representative of both his sawmill and the local timber.

832.15--853

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832.15--853

832.15--853

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Hanks, Leland F.
1976. **How to predict lumber-grade yields for graded trees.** Northeast. For. Exp. Stn., Upper Darby, Pa.
9 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-20)

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# Annotated Bibliography on the Ecology and Reclamation of Drastically Disturbed Areas

USDA FOREST SERVICE GENERAL TECHNICAL REPORT NE-21
1976

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082

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MANUSCRIPT RECEIVED FOR PUBLICATION 29 MARCH 1974

## ABSTRACT

This bibliography contains 591 annotated references to literature, mainly on mining effects and reclamation in the coal regions of the United States. Each reference is indexed by area, material (coal, ore waste, etc.), and general subject.

# Annotated Bibliography on the Ecology and Reclamation of Drastically Disturbed Areas

by
Miroslaw M. Czapowskyj

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## INTRODUCTION

THE UNITED STATES of America is fortunate in having a wealth of both renewable and nonrenewable natural resources. The latter — coal, metal ores, kaolin clay, phosphate, gravel and sand, and many others— are being mined continuously.

Surface-mining is the most common and perhaps the oldest, safest, and most economical method of recovering the commodity. But it drastically disturbs the land surface, spoils the landscape, and creates serious environmental problems.

Although estimates vary, available sources indicate that there are nearly 4 million acres of disturbed lands in the United States. In many Eastern States these disturbed areas are a significant component of the landscape. Because these lands contribute to an overall degradation of the environment, they have become a matter of great concern to many people and to government agencies at various levels.

While there has been substantial growth and expansion in the mining industry, the urgency of land reclamation has been recognized. Reclamation laws have been passed by State and local governments, and the surface-mining industry has faced up to the problems of disturbed-land reclamation.

However, in contrast to the technological advances in the recover and processing of natural resources, reclamation of drastically disturbed areas for diversified land use has not kept pace.

Attempts to rehabilitate surface-mined lands are not unknown to the strip-mining industry. Published reports on these efforts can be traced back to the turn of this century. Small-scale tree plantings and the establishment of other vegetation were the first attempts to correct the situation. The results were variable and erratic, and it was recognized that organized research was essential to land reclamation. Consequently, many universities, experiment stations, and Federal, State, and industrial institutions have initiated research programs designed to approach the many problems and to seek practical solutions to them. As a result, vast acreages of disturbed land have been turned into usable areas, and some have become community assets.

The activity in rehabilitation research of drastically disturbed lands has developed rapidly, yielding a voluminous literature. Several bibliographies, listing references on restoration of disturbed lands and associated problems in coal mining, have been compiled. Limstrom *(1953)* listed 135 references; Funk *(1962)* revised and expanded Limstrom's bibliography and listed 172 citations; Kieffer *(1972)* listed 700 citations, including M.S. and Ph.D. theses, mimeographed reports, and newspaper articles; and Munn *(1973)* compiled more than 600 references. A few bibliographies have appeared as appendices to printed reports. Other people have compiled listings dealing mainly with European work.

Special mention should be made of Mine Drainage Abstracts *(1964-73)* a bibliography published by Bituminous Coal Research Inc., of Monroeville, Pa., and supplemented annually. It contains lists and abstracts of literature dealing with mine-drainage research.

All these bibliographies are valuable sources of reference. However, with the exception of the bibliography on mine drainage and Munn's bibliography, none of them were annotated or systematically indexed. In addition, the supply of some of them is exhausted, and others are limited to narrow fields. Information is scattered in numerous professional and scientific publications, many of which are not readily available.

This bibliography grew from the need for an up-to-date compilation of the important

research literature dealing with the ecology of lands disturbed by surface mining.

Both basic and applied research findings, as well as reports on economic and political considerations pertaining to the problems, are included. The bibliography lists 591 references to publications by university, government, and industrial researchers. However, the major emphasis has been placed on research publications illustrating the accomplishments and the progress leading to improvement of the environment by minimizing erosion, alleviating air and water pollution, and improving the esthetics of affected areas.

Prime attention has been directed to work accomplished in the coal regions of the United States. Publications dealing with other than coal commodities or dealing with areas outside the United States have been included, provided they are relevant.

## ARRANGEMENT

This bibliography is presented in alphabetical order, by authors. Each reference contains an annotation — the essence of the publication.

For the convenience of those using this bibliography, each reference is followed by a group of key words and symbols. These represent three codes: to (1) area, (2) material, and (3) subject.

For example, **U. S.-PA : coal-B : VI-B** means that this reference deals with land disturbance in the United States, in Pennsylvania : the commodity is coal, bituminous : and the subject matter is reclamation, revegetation.

The codes follow:

### Area

#### UNITED STATES

| | |
|---|---|
| U.S. | United States |
| AL | Alabama |
| AZ | Arizona |
| CA | California |
| CO | Colorado |
| DE | Delaware |
| FL | Florida |
| GA | Georgia |
| HI | Hawaii |
| ID | Idaho |
| IL | Illinois |
| IN | Indiana |
| IA | Iowa |
| KS | Kansas |
| KY | Kentucky |
| ME | Maine |
| MD | Maryland |
| MI | Michigan |
| MS | Mississippi |
| MO | Missouri |
| MT | Montana |
| NV | Nevada |
| NM | New Mexico |
| ND | North Dakota |
| OH | Ohio |
| OK | Oklahoma |
| PA | Pennsylvania |
| TN | Tennessee |
| TX | Texas |
| UT | Utah |
| VA | Virginia |
| WV | West Virginia |
| WY | Wyoming |

#### CANADA

Canada

| | |
|---|---|
| AB | Alberta |
| BC | British Columbia |
| NB | New Brunswick |
| ON | Ontario |

(Note: other countries are spelled out.)

### Material

Coal:

- A Anthracite
- B Bituminous
- L Lignite
- R Breaker refuse

Kaolin clay
Phosphates
Ore waste
Sand and gravel
Bauxite
Fuel ash
Other

**Subject**

I. GEOLOGY AND PHYSIOGRAPHY
- A. Coal reserves and seam nomenclature
- B. Surveys

II. MINING OPERATIONS
- A. Equipment
- B. Methods
- C. Spoil placement
- D. Roads

III. SPOIL CHARACTERISTICS
- A. Classification and survey
- B. Chemistry, acidity, toxicity, minerology, and fertility
- C. Physics and mechanics
- D. Microbiology

IV. HYDROLOGY
- A. Infiltration
- B. Surface runoff
- C. Subsurface flow
- D. Streamflow
- E. Erosion and sedimentation
- F. Geochemistry
- G. Biology
- H. Impoundments

V. ENVIRONMENT
- A. Air pollution
- B. Water pollution
- C. Landslides

VI. RECLAMATION
- A. Land treatment
- B. Revegetation

VII. LAND USES FOR RECLAIMED AREAS
- A. Esthetics
- B. Watershed protection
- C. Agriculture
- D. Forests
- E. Wildlife habitat
- F. Recreation
- G. Fish habitat

VIII. MISCELLANEOUS
- A. Political considerations
- B. Economic considerations
- C. Research programs
- D. Symposium proceedings
- E. Bibliographies

## LITERATURE REFERENCES


1. Adams, L. M., J. P. Capp, and E. Eisentrout.
1971. **Reclamation of acidic coal-mine spoil with fly ash.** U.S. Dep. Inter. Bur. Mines Rep. Invest. 7504. 29 p., illus.

The spoils were treated with fly ash and were planted with a variety of grasses, legumes, trees, and shrubs. Greatest promise for growth was shown by Ky-31 fescue, rye, red top grasses, and birdsfoot trefoil, a legume. Survival of trees and shrubs was negligible. Addition of fly ash increased spoil pH to a range tolerable to plant growth and improved the physical characteristics of the spoil.

**U.S.-WV : coal-B : VI-B**

2. Adams, L. M., J. P. Capp, and D. W. Gillmore.
1972. **Coal mine spoil and refuse bank reclamation with powerplant fly ash.** Compost Sci. 13 (6) : 20-26.

Reclamation of coal-mine spoil and mine refuse with powerplant fly ash produced the following benefits: partial neutralization of acid spoil materials and increased moisture-holding capacity and pore space. A quick cover of certain grasses and legumes reduced erosion and stream-pollution potentials. The forage yields were comparable with yields from undisturbed areas.

**U.S.-WV, PA : coal-B : VI-B**

3. Agnew, Allen F., and Don M. Corbett.
1973. **Hydrology of a watershed containing flood-control reservoirs and coal surface-mining activity, Southwestern Indiana.** *In* Ecology and Reclamation of Devastated Land vol. 1: 159-173. Gordon and Breach Sci. Publ., New York.

Studies in Indiana showed that surface mining for coal can provide additional supplies

of groundwater, aid in flood control, and alter the water quality. Proper management of releases of water by the mining process can remedy the problem of acid mine drainage.

**U.S.-IN : coal-B : IV**

4. Aguar, Charles E.
   1971. **Mining and reclamation as related to state, regional and national land use plans, goals and requirements.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 11-14. Ga. Surface Mined Land Use Board. Macon.

The author discusses the national, state and regional reclamation use plans, goals, and requirements. He reports ". . . presently there are few clear cut, State, Regional or National Land Use Plans, Goals and Requirements to which mining and reclamation *can* relate."

**U.S.-GA : other : VIII-A**

5. Aharrah, Ernest C., and Richard T. Hartman.
   1973. **Survival and growth of red pine on coal spoil and undisturbed soil in western Pennsylvania.** *In* Ecology and Reclamation of Devastated Land vol. 1: 429-444. Gordon and Breach Sci. Publ., New York.

Comparisons were made of 20-year-old red pine (*Pinus resinosa* Ait.) plantations growing on spoil and on an adjacent old-field site. Volume increment, total volume, height, 5-year intercept, and diameter parameters were reported for each stand. The old-field site quality exceeded that of the spoil. Percent survival was higher on the spoil than in the old field, though the old field showed greater growth.

**U.S.-PA : coal-B : VI-B**

6. Aldon, Earl F., O. D. Knipe, and George Garcia.
   1973. **Revegetating devastated sites in New Mexico with western wheatgrass transplants.** USDA For. Serv. Res. Note RM-243. 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Western wheatgrass survived well and produced daughter plants from rhizomes during the first year when good seeds were grown to 3-month-old transplants then transferred to sandy or clay loam sites at elevations of about 7,500 feet.

**U.S.-NM : other : VI-B**

7. Aldon, Earl F., and H. W. Springfield.
   1973. **Revegetating coal mine spoils in New Mexico: a laboratory study.** USDA For. Serv. Res. Note RM-245. 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Emergence and early growth of mountain rye and fourwing saltbush were studied in untreated 3-year-old mine spoils and in spoils to which organic matter or fertilizer had been added under greenhouse conditions. Emergence and growth were satisfactory from untreated spoils; adding amendments had no effect on seedling emergence or early growth.

**U.S.-NM : coal : VI-B**

8. Allen, Natie, Jr.
   1973. **Experimental multiple seam mining and reclamation on steep mountain slopes.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 98-104. Bitum. Coal Res., Inc., Monroeville, Pa.

TVA was given the responsibility for planning a mining and reclamation method that would permit mining on *stripped slopes* but avoid the problems of unstable piles and highwalls. The method was tested in an area where four seams could be stripped and augered. Excess spoil was hauled to a previously mined pit. As stripping and augering progressed, overburden was used to fill in vacated pits. A bench on the outer slope was kept clear of spoil for a roadway. The final slope was graded and hydroseeded.

**U.S.-AL : coal-B : II-C**

9. Alverson, Kent.
   1973. **Cattle and catfish on surface-mined land.** Soil Conserv. 34 (4): 4-6, illus.

A story of a successful fish-farming operation

in strip-mine ponds, and cattle raising on reclaimed spoil banks.

**U.S.-IL : coal-B : VII-C+G**

10. Arata, Andrew A.
**1959. Ecology of muskrats in strip-mine ponds in southern Illinois.** J. Wildl. Manage. 23 (2) : 177-186.

The biology and ecology of muskrats in strip-mine ponds were studied. Averages of 2.8 dens per acre and 2.4 dens per 1,000 feet of shoreline were recorded. Cattail, sweet clover, broom-sedge, and goldenrod formed the summer diet, and cattail rootstocks and willows composed the winter diet. Intensive management for muskrats on strip-mined lands is not recommended.

**U.S.-IL : coal-B : VII-E**

11. Ashby, William C., and Malchus B. Baker, Jr.
**1968. Soil nutrients and tree growth under black locust and shortleaf pine overstories in strip-mine plantings.** J. For. 66: 67-70.

Tree growth and soil-nutrient levels were studied in a southern Illinois strip-mined area. Heights of black walnut, yellow-poplar, silver maple, and osage orange underplanted in a black locust plantation were greater than heights on shortleaf pine plots. Soil from the locust plantation was more productive than soil from the pine plantation. Nitrogen added to the plots tended to equalize plant growth on the two soils; adding phosphorus with nitrogen greatly enhanced growth on both soils.

**U.S.-IL : coal-B : VI-B**

12. Ashby, William C., Malchus B. Baker, Jr., and John B. Casteel.
**1966. Forest cover changes in strip-mine plantations.** Tree Planters' Notes 76: 17-20 p.

Describes changes in numbers and basal area in a black locust and shortleaf pine plantation on surface-mined land following severe climatic stress. An extremely cold winter was followed by a drought. Changes in understory planted and volunteer species composition were also noted.

**U.S.-IL : coal-B : VI-B**

13. Augustine, Marshall T.
**1966. Using vegetation to establish critical areas in building sites.** Soil Conserv. 32 (4) : 78-80, illus.

The capabilities and limitations of lower vegetation for stabilizing road cuts and building sites are discussed. Successful examples are given.

**U.S.-MD : other : V-C + VII-A**

14. Averitt, Paul.
**1970. Stripping-coal resources of the United States — January 1, 1970.** U.S. Geol. Surv. Bull. 1322. 34 p.

An analysis, by states, of the geologic and technologic sources of information about stripping coal as of 1 January 1970. The remaining coal recoverable by stripping in the U.S. in the 0- to 150-foot-thick overburden totaled 128 billion tons. The estimated recoverable coal is distributed in 26 states. Large amounts are concentrated in the northern Great Plains, North Dakota, Montana, Wyoming, Illinois, and the northern half of the Appalachian Basin.

**U.S. : coal : I-A**

15. Baker, Michael, Jr., Inc.
**1973. Analysis of pollution control costs.** Appalachian Reg. Comm. 436 p. Washington, D. C.

This report provides the data needed by the Appalachian Regional Commission for estimating costs of pollution abatement in the Monongahela River basin. The subject matter is divided into two parts: (1) abatement of coal-mine drainage pollution and mining-related problems; and (2) abatement of pollution from sources other than coal mining. The report contains about 275 references to publications and nearly 200 tables and figures.

**U.S.-WV, PA, MD, OH : coal-B : VIII-B**

16. Barnhisel, R. I., and H. F. Massey.
**1969. Chemical, mineralogical and physi-**

**cal properties of eastern Kentucky acid-forming coal spoil materials.** Soil Sci. 108: 367-372.

Spoil materials are characterized with respect to chemical, mineralogical, and physical properties. The extreme acidity of spoils and toxic levels of Fe, Mn, Cu, and Zn pose a problem in the establishment of plant cover. The deep burial of potentially toxic ion-producing material or the addition of limestone to neutralize the acids is suggested.

**U.S.-KY : coal-B : III-B**

17. Barnhisel, R. I., and Armine L. Rotromel.
1974. **Weathering of clay minerals by simulated acid coal spoil-bank solutions.** Soil Sci. 118(1): 22-27.

Kaolinite and mica-clay minerals were subjected to simulated sulfuric acid coal strip-mine solutions for periods up to 6 months. These data indicate that the mode of attack of the acid on both clays was at the edges. The acid released Al, Fe, K, Si, and possibly other ions to the solution phase, thereby serving as one possible explanation for the large amounts of $AL^{3+}$ found in coal spoil solutions. It seems that for mica the dissolution of the edges (octahedral layer) precedes the removal of $K^+$ from the interlayer positions. The rate of dissolution of kaolinite and mica were similar, and one would not expect large changes in mineralogies of natural spoil-bank materials from acid dissolution when these spoil materials are dominated by these two minerals.

**U.S.-KY : coal-B : III-B**

18. Barry, Frank J.
1965. **Federal and state regulation and the legislative picture.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 35-41. University Park.

A discussion of existing restrictions on blight, pollution, and despoilation caused by strip-mining, summarizing the similarities and recent changes of state strip-mine-reclamation laws and criticism of these laws and their administration. Provisions of the Appalachian Regional Development Act of 1965 are presented. Alternatives for the prevention of future damage from surface mining are considered.

**U.S. : Coal : VIII-A**

19. Bartee, L. D.
1964. **Evaluation of mulch materials for establishing vegetation on small dams.** J. Soil and Water Conserv. 19 (3): 117-118.

Mulch materials (hay, wood pulp, and forage sorghum) were used in establishing vegetation on small dams. All mulch material used resulted in satisfactory stands of vegetation. Some cost figures are given.

**U.S.-TX : other : VI-B**

20. Bauer, Anthony M.
1965. **Simultaneous excavation and rehabilitation of sand and gravel sites.** Nat. Sand and Gravel Assoc. Silver Spring, Md. 60 p. illus.

Industry views on site and operational factors of the sand and gravel industry. Factors that usually influence the planning process, and procedures for development of the ultimate use of sand and gravel sites, are discussed.

**U.S. : Sand and gravel : VI**

21. Bauer, Hermann Josef.
1973. **Ecological aerial photo interpretation for revegetation in the Cologne lignite district.** *In* Ecology and Reclamation of Devastated Land vol. 2: 469-476. Gordon and Breach Sci. Publ., New York.

It is more effective to identify the ecological factors by aerial-photo interpretation — together with terrestrial investigations — than by use of maps. Diagnosis of the ecological structure of the mined area permits a statistical assessment of the ecotopes and evaluation of their natural potential. Photo-interpretation can be used to identify ecologically important ecotopes that merit protection. It promotes a development of landscape planning on an ecological basis and of different measures for reclamation.

**Germany : coal-L : I**

22. Bauer, Hermann Josef.
1973. **Ten years' studies of biocenological succession in the excavated mines of the Cologne lignite district.** *In* Ecology and Reclamation of Devastated Land vol. 1: 271-283. Gordon and Breach Sci. Publ., New York.

Analysis of the various ecotopes with respect to soil microclimate, plants, and animals gave insight into the sequence of the biocenological succession. The abiotic factors of spoils — extreme edaphic, hydrologic, and microclimatic conditions—render the development of vegetation difficult. Yet there is a spontaneous colonization of plants; ecological conditions are changing; and there are successions in plant associations and animals. New lakes and their environs affect the ecoclimate and provide new areas for plants and animals. Associations come into existence that were unknown before mining.

**Germany : coal-L : VI-B**

23. Beattie, James M.
1957. **Foliar analysis shows value of spoils bank for fruit plantings.** Ohio Farm and Home Res. 42: 65-67.

Spoil and foliar-analyses techniques were used to predict fertilizer needs for fruit crops. It was found that neutral and slightly alkaline spoils are suited for the growth of peach trees provided ¼ pound of 33-percent N carrier per year of tree age is added. Alkaline spoils require addition of Mn. Very acid sands and shales are not suited for fruit trees. Freedom from frost damage should be considered.

**U.S.-OH : coal-B : VI-B**

24. Beck, R. E.
1973. **The North Dakota Surface Mining Control and Reclamation Law.** *In* some environmental aspects of strip mining in North Dakota. ND Geol. Surv. Educ. Ser. 5: 109-118.

The Surface Mining Control and Reclamation Law and its implication are discussed.

**U.S.-ND : coal : VIII-A**

25. Bengtson, G. W., D. A. Mays, and T. G. Zarger.
1971. **Techniques useful in establishing vegetative cover on reclaimed surface-mined lands.** Rehabil. Drastically Disturbed Surf. Mined Lands. Symp. Proc.: 79-86. Ga. Surface Mined Land Use Board. Macon.

Reclamation authorities, landowners, and the general public are demanding a professional job of land restoration and revegetation. The land reclaimer is expected to bring skills of agronomy and modern silviculture into play to establish a vigorous attractive cover. Methods adopted for soil do not always work on spoils. This is a comprehensive report on the present state of reclamation knowledge.

**U.S. : coal, other : VI-B**

26. Bengtson, G. W., D. A. Mays, and J. C. Allen.
1973. **Revegetation of coal spoil in northeastern Alabama: effects of timing of seeding and fertilization on establishment of pine-grass mixtures.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 208-214. Bitum. Coal Res., Inc., Monroeville, Pa.

One hundred plots were laid out so that a comparison could be made of all possible combinations of the following variables: seeding of three different grass species; no grass seeding; grass seeding in either of 2 consecutive years; fertilization at the rate of 0, 50, or 100 pounds N/acre; fertilization either all in the first year of the study or half in the first year and half in the following year; grading of plots several months before seeding; and grading at the time of seeding. All test plots were seeded to loblolly pine at the start of the tests. Results of the 3-year study showed that, where grasses and pines were seeded together, pine seedlings had difficulty surviving. Where pine was seeded alone, there seemed to be better germination and survival.

**U.S.-AL : coal-B : VI-B**

27. Bengtson, G. W., S. E. Allen, D. A. Mays, and T. G. Zarger.
1973. **Use of fertilizers to speed pine establishment on reclaimed coal-mine spoil in northeastern Alabama: I. Greenhouse experiments.** *In* Ecology and Reclamation of Devastated Land vol. 2: 199-225. Gordon and Breach Sci. Publ., New York.

Results of greenhouse experiments where coal-mine spoils were used as media for seeding loblolly pine. Seedlings responded to complete fertilizer, and the response was enhanced when fresh pine duff was added. N and P were found to be the only inorganic nutrients limiting pine growth. An evaluation was made of effects of concentrated superphosphate and several N-P fertilizer mixtures applied at the time of seeding.

**U.S.-AL : coal-B : VI-B**

28. Berg, William A.
1961. **Determining pH of strip-mine spoils.** USDA For. Serv. Res. Note NE-98. 7 p., illus. Northeast For. Exp. Stn., Upper Darby, Pa.

For determining spoil pH, the LaMotte-Morgan method produced results that usually agreed fairly well with results from using a pH meter on a 1:2 spoil:distilled water mixture. Results obtained with Soiltex and Hellige-Truog methods often deviated from the pH meter readings; and the Hydrion papers and the Kelway pH tester often gave results that were considerably different.

**U.S.-KY : coal-B : III**

29. Berg, W. A.
1965. **Plant-toxic chemicals in acid-spoils.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 91-94. University Park.

Hydrogen ions, aluminum, sulfate, total salts, Fe, and Mn and their importance to plant growth on acid coal-mine spoils are discussed. Al and Mn coming into solution as a result of extremely acid conditions are the elements most likely to cause plant toxicities on acid spoils.

**U.S.-KY : coal-B : III-B**

30. Berg, W. A.
1972. **Vegetative stabilization of mine wastes.** Colo. Min. Assoc. Min. Yearb. 1972: 24-26. Denver.

A brief report on vegetative stabilization of spoils and tailings in Colorado. Tailings vary considerably in physical and chemical characteristics, and in many places stabilization by means other than growing vegetation directly on the tailings is being used. Revegetation problems on spoils are not as complex as on tailings. Revegetation problems, besides limited moisture on spoils, include deficiency of N and often P.

**U.S.-CO : coal, Ore waste : VI-B**

31. Berg, William A.
1973. **Evaluation of P and K soil fertility tests on coal-mine spoils.** *In* Ecology and Reclamation of Devastated Land vol. 1: 93-104. Gordon and Breach Sci. Publ., New York.

The Bray test for P on 63 spoils from the southern Appalachian area was significantly correlated with plant growth response to added P. P extracted with 0.05N HC1+ 0.025N $H_2SO_4$ or with 0.15N $H_2SO_4$ was not correlated with response to added P. There was no yield response to K in these greenhouse studies. K-extracting solutions of 1N ammonium acetate, 0.15N $H_2SO_4$, and 0.05N HC1+ 0.025N $H_2SO_4$ all gave similar results on the spoil.

**U.S.-KY : coal-B : III-B**

32. Berg, W. A., and E. M. Barrau.
1972. **Composition and production of seedings on strip-mine spoils in Northwestern Colorado.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 215-224. Bitum. Coal Res., Inc., Monroeville, Pa.

Alfalfa dominated vegetation on strip-mine spoils in northwestern Colorado (about 7,000 feet elevation, 17 inches average annual precipitation) seeded 2 to 8 years previously with a mixture of grasses and legumes. Dry-matter production on spoils and soil-covered spoils was comparable when alfalfa was the dominant species. Total nitrogen in the soil-

size fraction of the spoils ranged from 545 to 1,205 ppm N as compared to 2,700 ppm for the surface soils in the area. The spoils contained about 70 percent coarse fragments and possibly have a more favorable moisture regime for growth of deep-rooted plants than the moderately fine to fine-texture soils common to the area.

**U.S.-CO : coal : VI-B**

33. Berg, W. A., and R. F. May.
1969. **Acidity and plant-available phosphorus in strata overlying coal seams.** Min. Congr. J. 55(3) : 31-34, illus.

Extremely acid strata were found in the burden on each of six coal strip-mines in eastern Kentucky. On four of the mines the extremely acid strata were rider coal seams or bone coal; on two mines the acid strata included shales. The overburden on all the mines was dominated by strata testing very low in plant-available phosphorus; however, there were strata on every mine that tested moderate in phosphorus.

**U.S.-KY : coal-B : III-B**

34. Berg, W. A., and W. G. Vogel.
1968. **Manganese toxicity of legumes seeded in Kentucky strip-mine spoils.** USDA For. Serv. Res. Pap. NE-119. 12 p., illus.

The occurrence of Mn toxicity was studied on six legumes grown in 46 acid strip-mine spoils from Kentucky. This toxicity was characterized by a distinct paling (chlorosis) on the leaf margins, readily seen on young leaves of all the species except Kobe lespedeza. Spoil pH was useful in predicting Mn toxicity on these legumes; water-soluble Mn extracted from the spoil was not.

**U.S.-KY : coal-B : III-B**

35. Berg, William A., and Willis G. Vogel.
1973. **Toxicity of acid coal-mine spoils to plants.** *In* Ecology and Reclamation of Devastated Land vol. 1: 57-68. Gordon and Breach Sci. Publ., New York.

Mn toxicity was observed on legume seedlings grown in extremely acid Pennsylvania strip-mine spoils. Al toxicity to seedlings grown on acid spoils was indicated by growth of stubby roots without laterals. Mulching of extremely acid spoils with hardwood chips resulted in significant decreases in total soluble salts and water-soluble Al.

**U.S.-KY : coal-B : III-B**

36. Beverly, R. G.
1968. **Unique disposal methods are required for uranium mill waste.** Min. Eng. 20(6) : 52-56.

Special methods for disposing of liquid effluents and stabilizing inactive uranium mill tailings are described.

**U.S.-CO : Ore wastes : VI-A, B**

37. Beyer, L. E., and R. J. Hutnik.
1969. **Acid and aluminum toxicity as related to strip-mine spoil banks in western Pennsylvania.** Pa. State Univ. Spec. Res. Rep. SR-72. 79 p., illus.

A report on the chemical properties of selected toxic spoils. Growth of birch and pine seedlings growing in nutrient solution was inversely proportional to spoil pH and concentration of Al. Comprehensive literature review.

**U.S.-PA : coal-B : III-B**

38. Biesterfeldt, R. C., and W. F. Mann, Jr.
1969. **New hope for strip-mine reclamation.** For. Farmer August 1969. 6-8.

Success was reported in establishing southern pines on strip-mine spoils with aerial sowing of coated seeds. The key to success was a seed coating that repels birds, rodents, and insects.

**U.S.-AL : coal-B : VI-B**

39. Bituminous Coal Research, Inc.
1964-1973. **Mine drainage abstracts — a bibliography.** Pa. Dep. Environ. Resour. Annu. Suppl. Harrisburg.

This series of annual abstracts contains more than 2,300 citations about the formation, abatement, and effects of water pollution related to both surface and underground mining of coal. The material is arranged according

to year of publication and is indexed by individual author, subject classification, geographic features, and organization.

**U.S. : coal : IV + VIII-E**

40. Blevins, R. L., H. H. Bailey, and G. E. Ballard.
1970. **The effect of acid mine water on floodplain soils in the western Kentucky coalfields.** Soil Sci. 110: 191-196.

P applied in the presence of lime to acid-contaminated spoils produced higher yields of corn than either lime or P applied alone. To reclaim mine-contaminated soils, install adequate drainage, protect the area from further contamination, adjust the pH to 6.0 to 6.5 with lime, and supply P and other fertilizers.

**U.S.-KY : coal-B : VII-C**

41. Boccardy, Joseph A., and Willard M. Spaulding, Jr.
1968. **Effects of surface mining on fish and wildlife in Appalachia.** U.S. Dep. Inter. Bur. Sport Fish. and Wildl. Resour. Publ. 65. 20 p., illus.

A report dealing with the extent and existing conditions of strip-mined land in Appalachia and the effects on fish and wildlife.

**U.S.-AL, KY, OH, PA, TN, VA, WV : coal-B : VII-E**

42. Boesch, Mark J.
1974. **Reclaiming the strip mines at Palzo.** Compost Sci. 15(1) : 24-25.

Application of sewage sludge and contouring were essential for successful revegetation of strip-mine spoils.

**U.S.-IL : coal-B : VI-B**

43. Bowden, Kenneth L., and Richard L. Meier.
1961. **Should we design new "badlands"?** Landscape Archit. 51 (4) : 224-229.

The authors suggest that we turn the strip-mined lands into useable recreational areas by creating new "badland areas" especially in the monotonous Midwest.

**U.S. : coal-B : VII-F**

44. Boyce, Leon.
1972. **Results of soil stabilization tests with fly ash and calcium sulfate sludge.** Univ. Kans. State Geol. Surv. Spec. Distrib. Publ. 65: 3-6. (1972 Mined Land Workshop Proc.)

Application of soil-stabilization techniques to mine spoils by using fly ash and calcium sulfate sludge is suggested.

**U.S.-KS : coal-B : VI-B**

45. Boyce, Stephen G., and Robert W. Merz.
1959. **Tree species recommended for strip-mine plantations in western Kentucky.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 160. 12 p., illus. Columbus, Ohio.

Twelve species of trees, mainly hardwoods, were planted on strip-mined lands in western Kentucky. Ten-year results showed that all were suitable for plantings on at least some spoil-bank sites. Survival and growth varied widely among sites and species. For optimum survival and growth, species should be selected carefully for the various sites, and only the best stock should be used.

**U.S.-KY : coal-B : VI-B**

46. Boyce, Stephen G., and David J. Neebe.
1959. **Trees for planting on strip-mined land in Illinois.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 164. 33 p., illus. Columbus, Ohio.

Seventeen species of trees were found suitable for planting on strip-mined land in Illinois. Ten species were suitable for planting in all parts of the State; seven additional species were suitable for the southern counties. The best performance was obtained where species were selected for the various sites and the best quality stock was planted. The species selected and their suitability are summarized.

**U.S.-IL : coal-B : VI-B**

47. Braley, S. A.
1952. **Experimental strip mines show no stream pollution.** Min. Congr. J. 38(9) : 50, 67, illus.

Acid pollution of streams could be minimized by following three rules: (1) keep surface water from the surrounding area out of the pit by a ditch circling the mine on the uphill side; (2) keep sulfur-bearing material out of the way of flowing water; and (3) while backfilling, bulldoze the sulfur-carrying material against the foot of the highwall and cover it with several feet of compacted material removed from the surface.

**U.S.-PA : coal-B : V-B**

48. Braley, S. A.
1954. **Summary report of Commonwealth of Pennsylvania (Department of Health) Industrial Fellowship 1 to 7 incl. Mellon Ins. Ind. Res. Fellowship 326B.** 279 p. Pittsburgh.

Results of investigation on the nature and composition of coal-mine discharge; the source and reaction by which it is found; the role of bacteria; the methods by which acid is carried through and from mines; the relationship between concentration and volume of flow on a seasonal basis; the seasonal effects on streams; and the effects of self-purification on streams.

**U.S.-PA : coal-B : VIII-C**

49. Braley, S. A.
1954. **Acid mine drainage: problem.** Mechanization 18 (1): 87-89.

Water is today one of our most valuable natural resources. Conservation of this resource and the prevention of pollution is becoming an increasingly important problem of American industry.

**U.S.-PA : coal-B : V-B**

50. Braley, S. A.
1954. **Acid mine drainage: source.** Mechanization 18 (2): 113-115.

This second of a series of articles deals with the materials and chemical reactions involved in the formation of acid in mine water, explaining why these reactions occur more rapidly in mines than under laboratory conditions.

**U.S.-PA : coal-B : V-B**

51. Braley, S. A.
1954. **Acid mine drainage: sampling and analysis.** Mechanization 18 (3): 96-98.

A method of taking a proper representative sample of mine or stream water and how to handle it prior to analysis. Also described are laboratory methods of determining the acidity and pH of the sample. The relationship between actual acidity and pH of the stream samples is discussed.

**U.S.-PA : coal-B : V-B**

52. Braley, S. A.
1954. **Acid mine drainage: composition and flow.** Mechanization 18 (4): 137-138.

A list of sample data obtained from the sampling of streams into which acid mine water is discharged. The author demonstrates how such data must be interpreted and concludes that each mine must be studied separately to determine its effect on stream pollution. No overall rule can be established that will cover all cases of mine-water discharge.

**U.S.-PA : coal-B : V-B**

53. Braley, S. A.
1954. **Acid mine drainage: control of mine acid.** Mechanization 18 (5): 97-98.

There is no known economical or practical method for positive control of mine acid discharge from underground bituminous coal mines, although various methods have been tried.

**U.S.-PA : coal-B : V-B**

54. Braley, S. A.
1954. **Acid mine drainage: control of oxidation.** Mechanization 18 (6): 105-107.

The results obtained from samplings of drainage and atmosphere from sealed and abandoned mines over a 5-year period. Results of these experiments indicate that sealing of mines to control oxidation, and therefore acidity, is of doubtful value unless the mine is below drainage level.

**U.S.-PA : coal-B : V-B**

55. Braley, S. A.
1954. **Acid mine drainage: strip mines.** Mechanization 18 (8) : 101-103.

A practical method by which formation of acid water in open-pit mines may be eliminated or greatly reduced. The prescribed method, involving proper drainage, segregation of the sulfuritic material, and proper backfilling, can be accomplished with little additional cost to the mine operator.

**U.S.-PA : coal-B : V-B**

56. Braley, S. A.
1957. **Evaluation of mine drainage water.** Min. Eng. 9 (1) : 76-78.

Sulfate salts of Fe and Al are prime causes of water acidity. The author discusses the methods of determining the quality of mine drainage and the criteria that are used; pH, free acidity, and total acidity, the last being one factor most valuable for determining the quality of mine water.

**U.S.-PA : coal-B : V-B**

57. Braley, S. A.
1965. **The Humphrey project.** Acid Mine Drain. Res. Symp. 1 Proc.: 167-176. Bitum. Coal Res., Inc., Monroeville, Pa.

Discusses an experiment on handling the water underground by transporting it in pipes, so that there is no chance of its running into open ditches or contacting the bottom of the mine or coming in contact with oxidizable material. This experiment is based on the theory "that if the water entering the mine from underground channels is alkaline, it will remain so if contact with acidic materials can be prevented."

**U.S.-WV : coal-B : IV-C + V-B**

58. Bramble, W. C.
1949. **Strip mining—waste or conservation?** Am. For. 55 (6) : 24-25, 42-43, illus.

Strip-mining is the most economical and safest way to mine coal, but it despoils the land. The way Pennsylvania is meeting the problem is reported in this article.

**U.S.-PA : coal-B : VI**

59. Bramble, William C.
1952. **Reforestation of strip-mined bituminous coal land in Pennsylvania.** J. For. 50 : 308-314.

Site factors that affect tree survival on coal-mine spoils are: fine soil content, acidity, wind exposure, soil temperature, slope, and forest material. An aspen-fire cherry community is the initial stage on ungraded spoils. Successful reforestation is possible in spring and fall with many tree species. Reclamation programs are discussed.

**U.S.-PA : coal-B : III + VI-B**

60. Bramble, W. C., and R. H. Ashley.
1950. **Spoil bank planting — fall, 1949.** Pa. State Coll. Agric. Exp. Stn. Prog. Rep. 24. 6 p., illus.

Survival ranged from unsatisfactory to good, depending on spoil type and acidity. Strongly acid carbonaceous shale and acid sandstone spoils produced low survival; moderately acid shales and glacial till spoils gave satisfactory results. A scheme for determination of spoil types is given.

**U.S.-PA : coal-B VI-B**

61. Bramble, William C., and Roger H. Ashley.
1955. **Natural revegetation of spoil banks in central Pennsylvania.** Ecology 36 : 417-423, illus.

The pioneer community was dominated by trees and shrubs capable of invading the spoils by seeds transported by wind and animals. An aspen-fire cherry community has been found as the most common on upland spoil banks. Blackberry, sweetfern, sumac, and prairie willow were characteristic shrubs. Herbs and grasses formed the ground layer. The game food and cover were of low value.

**U.S.-PA : coal-B : VI-B**

62. Bramble, William C., Henry R. Chisman, and Glenn H. Deitschman.
1948. **Research on reforestation of spoil banks in Pennsylvania.** Pa. State Univ. For. Sch. Res. Pap. 10. 6 p.

Good early survival has been obtained with red and Banks pines, Japanese larch, red oak, and black locust on acid shale and sandstone spoils. These species will grow well on a wide range of acid spoils, at least till 10 years of age. Black locust grows well up to 12 years and then begins to deteriorate.

**U.S.-PA : coal-B : VI-B**

63. Bramble, W. C., and Ward M. Sharp.
1949. **Rodents as a factor in direct seeding on spoil banks in central Pennsylvania.** J. For. 47: 477-478.

Rodent control seems to be necessary for successful fall seeding on strip-mine spoils.

**U.S.-PA : coal-B : VI-B**

64. Branson, Branley A., and Donald L. Batch.
1972. **Effects of strip-mining on small stream fishes in east central Kentucky.** Biol. Soc. Wash. Proc. 84(59): 507-517.

A low-level of acid mine drainage but a high level of siltation and turbidity was observed. Fishes were progressively eliminated from water downstream. Food organisms were reduced; reproduction was curtailed. Some fish species are resistant to silt and turbidity and are able to subsist despite silting of the bottom.

**U.S.-KY : coal-B : VII-E**

65. Brant, Russell A.
1964. **Geological description and effects of strip mining on coal overburden material.** Ohio J. Sci. 64 (2): 68-75.

Discusses the geology of the coal-bearing region of Ohio and the occurrence of the principal coal beds with respect to the geological groups in which they are found. The relationship of the geology to some of the physical and chemical changes that affect overburden material in strip-mine spoils is discussed.

**U.S.-OH : coal-B : I + III**

66. Brant, Russell A., and Richard M. DeLong.
1960. **Coal resources of Ohio.** Ohio Dep. Nat. Resour. Div. Geol. Surv. Bull. 58. 245 p., illus.

Estimates of coal reserves in Ohio. The coal is found in 24 beds of 14 or more inches thick, which occur in 32 counties in eastern and southeastern Ohio. Geography and geology of each county is given. Tables, maps, and appendices.

**U.S.-OH : coal-B : I-A**

67. Brant, Russell A., and Edward Q. Moulton.
1960. **Acid mine drainage manual.** Ohio State Univ. Eng. Exp. Stn. Bull. 179. 40 p., illus.

A summary of information about the acid drainage from Ohio coal mines. Fundamental factors of acid formation, geology, chemistry, minerology, bacteriology, hydrology, and coal-mine operations are discussed. The principles of alleviation procedures currently being employed such as good housekeeping, exclusions, flow regulation, reclamation, and treatment are described.

**U.S.-OH : coal-B : III-B + VI**

68. Breathitt, Edward T.
1965. **Strip mining in Kentucky.** Ky. Dep. Nat. Resour. Strip Mine Reclam. Symp. Proc.: 45-47. Frankfort.

Discusses involvement of the state agencies, coal industries, and others in reclamation efforts on strip-mined lands.

**U.S.-KY : coal-B : VIII-A**

69. Brooks, David B.
1965. **Spoil bank reclamation: some economic observations.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 64-71. University Park.

A discussion of economics in reclamation of coal-mine spoils, including potential usefulness of benefit-cost analysis for making decisions about the reclamation process.

**U.S. : coal : VIII-B**

70. Brooks, David B.
1966. **Strip-mine reclamation and economic analysis.** Nat. Resour. J. 6(1): 13-44.

It is suggested that a rational allocation of

resources can be made through benefit-cost analysis. Goals used are national productivity, cultural and aesthetic values, and local employment.

**U.S. : coal : VIII-B**

71. Brown, Grover F.
1949. **Strip-mining and land restoration.** Soil. Conserv. 15 (5) : 107-109, illus.

Discussing the use of open-cast coal-mining in England, the author suggests that some of the coal-mining methods used there should be applied in the United States.

**Great Britain : coal : VI**

72. Brown, James H.
1962. **Success of tree planting on strip-mined areas in West Virginia.** W. Va. Univ. Agr. Exp. Stn. Bull. 473. 35 p., illus. Morgantown.

Ten tree species planted on West Virginia strip-mine spoils were evaluated on a variety of spoil and site conditions. Many species survived well (49 to 80 percent). Black locust and Scotch, red, and white pines performed best. Survival was correlated with precipitation during early periods of the first growing season; black locust performance was correlated with slope.

**U.S.-WV : coal-B : VI-B + VII-D**

73. Brown, James H.
1971. **Use of trees for revegetation of surface-mined areas.** W. Va. Univ. Symp. Reveg. and Econ. Use of Surf.-Mined Land and Mine Refuse Proc.: 26-28. Morgantown.

An overall review of site factors affecting establishment and growth on strip-mine spoils and a discussion of performance of most commonly planted species.

**U.S.-WV : coal-B : VI-B**

74. Brown, James H.
1973. **Height growth prediction for black locust on surface-mined areas in West Virginia.** W. Va. Univ. Agric. Exp. Stn. Bull. 617. 11 p. Morgantown.

Sixty percent of the variation in height growth of black locust was accounted for for four of the variables: percent slope, aspect, elevation, and extent of regrading. Using a multiple-regression equation, a table was constructed that can be used for estimating the height growth of black locust on surface-minded spoils.

**U.S.-WV : coal-B : VI-B**

75. Brown, James H.
1973. **Site factors and seeding methods affecting germination and survival of tree species direct-seeded on surface-mined areas.** West Va. Univ. Agric. Exp. Stn. Bull. 620. 25 p. Morgantown.

Germination, survival, and percent stocking of direct-seeded, unscarified black locust were related to variations in moisture and temperature. Seed treatment, species, and seedbed condition also affected germination and survival.

**U.S.-WV : coal-B : VI-B**

76. Brown, James H., and E. H. Tryon.
1960. **Establishment of seeded black locust on spoil banks.** W. Va. Agric. Exp. Stn. Bull. 440. 34 p., illus. Morgantown.

A survey of West Virginia spoils seeded to black locust and of vegetation occurring naturally showed that only on 20 percent of the area seeded to black locust had adequate cover been obtained; average stocking was 40.4 percent. Thirty-seven woody species seeded naturally on spoils with pH 4.0 and above; below pH 4.0 there was no vegetation. Establishment of woody seedlings is indirectly related to percent of slope.

**U.S.-WV : coal-B : VI-B**

77. Brown, Ray W.
1973. **Transpiration of native and introduced grasses on a high-elevation harsh site.** *In* Ecology and Reclamation of Devastated Land vol. 1: 467-481. Gordon and Breach Sci. Publ., New York.

Transpiration rates of Kings fescue, smooth brome, and intermediate wheatgrass were measured in the Wasatch Mountains in Utah.

The highest rates were obtained by the smooth brome and wheatgrass. Diurnal changes in leaf temperature corresponded to the transpiration rates. Transpiration responses of plants to micro-environmental fluxes seem to be important in determining the adaptability of species to hard conditions.

**U.S.-UT : other : VI-B**

78. Bruce, R. R., and E. A. Thurn.
1955. **The potentialities of revegetating and utilizing agronomic species on strip mined areas in Illinois.** Univ. Ill. Agric. Exp. Stn. and Ill. Coal Strippers Assoc. 7th and 8th Yr. Prog. Rep. 34 p., illus.

A progress report on research into possibilities of revegetating and utilizing strip-mined lands for forage and grain crops. In this phase, studies were narrowed down, intensified, and limited to graded mine spoils. This report concerns principally the physical properties of leveled mined land, with attempts to determine any physical changes due to weathering or vegetative treatments that affect crop yields. Vegetative growth response to fertilizer was studied.

**U.S.-IL : coal-B : III + VII-C**

79. Buchauer, Marilyn J.
1973. **Contamination of soil and vegetation near a zinc smelter by zinc, cadmium, copper and lead.** Environ. Sci. and Tech. 7 (2) : 131-135.

Metal oxide fumes escaping from two zinc smelters in Palmerton, Pa., have contaminated soil and vegetation with Zn, Cd, Cu, and Pb. Within 1 km of the smelters, 135,000 ppm Zn, 1,750 ppm Cd, 2,000 ppm Cu, and 2,000 ppm Pb have been measured in the $O_2$ horizon. Approximately 90 percent of metals deposited on the soil surface have been retained in the top 15 cm of the soil profile. Depauperate trees within 2 km of the smelters contained up to 4,500 ppm Zn and 70 ppm Cd by weight in washed oven-dried foilage.

**U.S.-PA : other : V-A**

80. Buckner, E. R., and J. S. Kring.
1967. **A crop for mine spoils?** Keep Tenn. Green Assoc. J. 7 (1).

A possibility of growing Christmas trees on strip-mine spoils is discussed. Early performance of the test plantings showed great variation in growth and color.

**U.S.-KY : coal-B : VII-D**

81. Bullard, Fred B.
1967. **The coal industry in Kentucky.** Ky. Dep. Nat. Resour. Strip-Min. Symp. 7 p. Frankfort.

The history of coal mining in Kentucky, and the place of coal mining in the State economy.

**U.S.-KY : coal-B : VIII-B**

82. Burner, Charles C.
1973. **Fishery Management in strip-mine lakes.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 304-318. Bitum. Coal Res., Inc., Monroeville, Pa.

A study of 10 strip-mine lakes in Kansas and 6 in Indiana demonstrated that strip-mine lakes can support a good quality sport fishery. Fish populations can be established in lakes that have drainage from a fairly large watershed instead of only adjacent spoil banks; have an area greater than ½ acre; have a depth of over 5 feet; and have a pH no less than 6. Fish-stocking guidelines for these waters are given.

**U.S.-KS, IN : coal-B : VII-G**

83. Busby, Jack K.
1965. **The role of private utilities in planning and implementing the orderly development of a region.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 28-34. University Park.

The author describes the role of the Pennsylvania Power and Light Company in planning and developing its service area. A tree-planting program, "Operation Trees", was designed to screen the anthracite strip-mine spoils.

**U.S.-PA : coal-A : VIII-B**

84. Callahan, John C., and Jacqueline G. Callahan.
1971. **Effects of strip mining and technological change on communities and natural resources in Indiana's coal mining region.** Purdue Univ. Res. Bull. 871. 43 p.

The effects of the strip-mining operation on the local community — including expenditures by companies in the communities, their tax contribution, and their effects on the tax base, employment, and income — are discussed. The present and potential effects of strip-mining on land-use changes, and the impacts on local and regional growth, demographic patterns, and social institutions, are pointed out.

**U.S.-IN : coal-B : VIII-B**

85. Camin, Kathleen Q.
1972. **Data collected from the demonstration sites.** Univ. Kans. State Geol. Surv. Spec. Distrib. Publ. 65: 21-23. (1972 Mined Land Workshop Proc.)

Grasslands demonstration projects show that: extensive soil testing is necessary, and fall plantings of fescue have been much more successful than spring plantings. The recommended seeding time is September.

**U.S.-KS : coal-B : VII-C**

86. Campbell, Robert S., Owen T. Lind, George L. Harp, William T. Geiling, and John E. Letter, Jr.
1965. **Water pollution studies in acid strip-mine lakes: changes in water quality and community structure associated with aging.** Acid Mine Drain. Res. Symp. 1 Proc.: 188-198. Bitum. Coal Res., Inc. Monroeville, Pa.

A report of research in progress on strip-mine lakes in Missouri. The tentative conclusions suggest that: (1) the most acid strip-mine lakes are chemically similar to acid underground mine discharges; (2) as the strip-mine lakes age, there is a progressive decline in acidity; and (3) associated with this decline in acidity is a loss in dissolved substances, an alteration in thermal stratification, an increase in the diversity of the biota, and a potential for greater total productivity.

**U.S.-MO : coal-B : IV-G**

87. Capp, John P., and D. W. Gillmore.
1973. **Soil-making potential of powerplant fly ash in mined-land reclamation.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 178-186. Bitum. Coal Res., Inc., Monroeville, Pa.

Treatment of coal wastes from surface and deep mining with fly ash results in a soil cover that will sustain grasses and legumes. The beneficial effects of using fly ash for this purpose are discussed, along with techniques for reclaiming with fly ash. Fly-ash reclamation of strip spoil and refuse banks may be cheaper than alternative methods.

**U.S.-WV : coal-B : VI-B**

88. Carpenter, Carl M.
1944. **Forestry and strip-mining.** Am. For. 50(2): 70-72, 94, illus.

Serious land problems are created by strip-mining operations, covering thousands of acres annually. Such land can be made to produce forest, recreation, and wildlife areas. Implementation of reclamation laws is discussed.

**U.S.-IN : coal-B : VII-D**

89. Caruccio, Frank T.
1973. **Characterization of strip-mine drainage by pyrite grain size and chemical quality of existing groundwater.** *In* Ecology and Reclamation of Devastated Land vol. 1: 193-226. Gordon and Breach Sci. Publ., New York.

The acidity of mine drainage from strip mines in Pennsylvania is determined by the oxidation rate of pyrite in the coal and associated strata, the presence of iron bacteria, and the neutralizing capacity of the existing groundwater. The first factor is dependent upon the pyrite granularity, and the last two are a function of the chemical composition of the mine strata. These can be used to delineate three horizons within the Allegheny group, each producing a chemically

characteristic mine drainage. By evaluating the pyrite in the mine strata and the chemistry of the existing groundwaters, areas can be outlined that will yield mine drainage that is (1) highly acid-high sulfate; (2) moderately acid-moderate sulfate; (3) neutral, negligible sulfate; and (4) neutral, moderate sulfate.

**U.S.-PA : coal-B : IV-F**

90. Cary, Herbert C.
1971. **Management plans.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 28-32. Ga. Surfaced Mined Land Use Board. Macon.

The development of a technically sound management plan is essential for successful reclamation. All options of land-use alternatives should be considered as well as short- and long-range aspects of mining and reclamation.

**U.S.-GA : coal, other : VIII**

91. Cederstrom, D. J.
1971. **Hydrologic effects of strip mining west of Appalachia.** Min. Cong. J 57(3): 46-50.

The author suggests the hydrologic advantages of disturbed ground. Strip-mined lands can be managed to diminish floods, increase low flow, and become a significant source of water.

**U.S.-IN, IL : coal-B : IV**

92. Chadwick, M. J.
1973. **Methods of assessment of acid colliery spoil as a medium for plant growth.** *In* Ecology and Reclamation of Devastated Land vol. 1: 81-91. Gordon and Breach Sci. Publ., New York.

Coal-spoil properties are discussed in relation to the chemical activity of detrital fraction, iron pyrites, ankerite, and amorphous material, and their interactions during the weathering process. A system is described that attempts to integrate these interactions by using a ratio between the total exchangeable acidity and cation exchange capacity on the one hand and the acid-extractable cations on the other. The results of controlled weathering are used to evaluate the system.

**Great Britain : coal : III-B**

93. Chadwick, M. J.
1973. **Amendment trials of coal spoil in the north of England.** *In* Ecology and Reclamation of Devastated Land vol. 2: 175-188. Gordon and Breach Sci. Publ., New York.

Six trials have been established on various spoil types. Liming, fertilizers, sewage sludge, shoddy, lagooned pulverized fuel ash, broiler manure, and cationic bitumen emulsion have been used as ameliorants. Trees, grass, and legume species have been sown. The effects of the ameliorants on spoil characteristics are considered, and the results of species performance are discussed and evaluated.

**Great Britain : coal : VI-B**

94. Chapman, A. G.
1944. **Forest planting on strip-mined coal lands with special reference to Ohio.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 104. 25 p., illus. Columbus, Ohio.

Three major groups of spoils were recognized. Group 1 — spoils of glacial till, sandstones, and acid silt shales; Group 2 — spoils of sandstones and acid silt shales; Group 3 — spoils of sandstones, mainly shales and limestone. Early performance of hardwoods and conifers as related to spoil material is given. Apparent causes of mortality and the management of black locust plantations are discussed.

**U.S.-OH : coal-B : VI-B**

95. Chapman, A. G.
1947. **Rehabilitation of areas stripped for coal.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 108. 14 p. Columbus, Ohio.

General discussion of strip-mine reclamation work in the Central States.

**U.S. : coal-B : VI**

96. Chapman, A. G.
1967. **Effects of spoil grading on tree growth.** Min. Congr. J. 53(8): 93-100.

The author discusses effects of spoil grading as related to compaction and the resulting effects on water absorption, erosion, and tree survival. Reports on tree species' performance on various spoil types and grading conditions.

**U.S.-OH, KS, MO : coal-B : VI**

97. Chapman, A. G.
1967. **How strip-land grading affects tree survival and growth.** S. Ill. Univ. Sch. Agric. Publ. 29. 34 p., illus.

The over-grading of strip-mine spoils high in plastic clay results in site compaction, which adversely affects both survival and growth of forest trees. The compacted spoils reduce air and water infiltration and increase water runoff; essential elements are less available; and biotic life is reduced. The spoils high in sand and in coarse fraction are not appreciably affected by grading. Physical and chemical characteristics of spoils are discussed.

**U.S.-KS, OH, IL, MO : coal-B : III + VI**

98. Charmbury, H. B.
1965. **Pennsylvania laws and reclamation programs.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 42-43. University Park.

The author reviews basic concepts of the Pennsylvania Bituminous Coal Open Pit Mining Conservation Act.

**U.S.-PA : coal-B : VIII-A**

99. Clark, F. Bryan.
1954. **Forest planting on strip-mined land in Kansas, Missouri and Oklahoma.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 141. 33 p., illus. Columbus, Ohio.

The author discusses the possibilities of using strip-mined areas for growing forest. Most of the mortality takes place during the first growing season. Fine-textured areas should be allowed to stabilize before planting. Tree performance was better on ungraded spoils and on slopes. Native species survived best. Recommendations for tree planting are presented.

**U.S.-KS, OK, MS : coal : VI**

100. Coal Industry Advisory Committee of the Ohio River Valley Water Sanitation Commission.
1964. **Principles and guide to practices in the control of acid mine-drainage.** Ohio River Valley Sanit. Comm. 30 p., illus.

A manual for the use of coal operators and officials of pollution-control agencies. Reviews the principles involved in the formation of acid mine drainage and presents a guide to control practices that will aid in ameliorating the effects of mine drainage on the streams and rivers of the Ohio Valley.

**U.S.-OH : coal-B : IV**

101. Coal Industry Advisory Committee to the Ohio River Valley Water Sanitation Commission.
1965. **Acid Mine Drain. Res. Symp. 1 Proc.:** 232. Bitum. Coal Res. Inc., Monroeville, Pa.

The volume contains 21 papers presented at the first symposium on acid mine drainage research held in May 1965 in Pittsburgh, Pa. Papers are grouped into following topics: (1) formation of acid mine water; (2) treatment of acid mine water; (3) control of acid mine drainage; (4) effects of acid mine drainage; (5) reclamation; and (6) Orsanco library.

**U.S. : coal : IV + VIII-D**

102. Coal Industry Advisory Committee to the Ohio River Valley Water Sanitation Commission.
1968. **Coal Mine Drain. Res. Symp. 2 Proc.** 406 p. Bitum. Coal Res., Inc., Monroeville, Pa.

The volume is a product of the second symposium on coal-mine drainage research held in May 1968 in Pittsburgh, Pa. It contains 27 papers grouped into following topics: (1) chemistry of mine drainage; (2) biology of mine drainage; (3) control measures; (4)

treatment techniques and (5) industry application of mine drainage control methods.

**U.S. : coal : IV + VIII-D**

103. Coal Industry Advisory Committee to the Ohio River Valley Water Sanitation Commission.
1970. **Coal Mine Drain. Res. Symp. 3 Proc.** 406 p. Bitum. Coal Res., Inc., Monroeville, Pa.

The volume is a product of the third symposium on coal-mine drainage research held in May 1970 in Pittsburgh, Pa. Most of the 28 reports include information not previously published. The reports are grouped under the following six topics, reflecting individual sessions: (1) neutralization of acid mine drainage; (2) formation of acid mine water; (3) novel approaches to mine drainage control; (4) demineralization of mine water; (5) abatement of mine drainage; and (6) sludge handling, disposal, and utilization.

**U.S. : coal : IV + VIII-D**

104. Coal Industry Advisory Committee to the Ohio River Valley Water Sanitation Commission.
1972. **Coal Mine Drain. Res. Symp. 4 Proc.** 435 p. Bitum. Coal Res., Inc., Monroeville, Pa.

This volume is a product of the fourth symposium on coal-mine drainage research held in April 1972 in Pittsburgh, Pa. It includes 31 papers grouped under six topics: (1) definition of the problem and some institutional approaches to the solution; (2) prevention and abatement; (3) new approaches to mine drainage treatment; (4) optimizing mine drainage neutralization; (5) detection and effects of coal mine drainage; and (6) application of technology and the results of research.

**U.S. : coal : IV + VIII-D**

105. Coates, William E.
1973. **Landscape architectural approach to surface mining reclamation.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 26-41. Bitum. Coal Res., Inc., Monroeville, Pa.

In the view of the landscape architect, strip-mining should be considered as an interim land use and provision must be made to return mined land to the highest and best use compatible with use of adjoining land. Advantages claimed for planning rehabilitation as part of the mining operation are low cost, reducing overburden handling and equipment movement, and minimal open raw areas at any time during the mining operation. The most immediate needs for vegetative cover, preventing erosion and improving the soil, can be met best by legumes and grasses. The author suggests the use of trees only for screening exposed highwall, for visual accents, or as sources of seed for volunteer seedlings where there is no nearby mature forest.

**Canada : coal, other : V**

106. Coleman, G. B.
1951. **A study of water infiltration into spoil banks in central Pennsylvania.** J. For. 49: 574.

An abstract of an M.S. thesis. It was found that the infiltration rates for dark shales were 65 to 397 inches per hour, Dekalb soil 17 to 60, and yellow shales 9 to 17.

**U.S.-PA : coal-B : IV-A**

107. Collier, Charles R., and others.
1964. **Influences of strip-mining on the hydrologic environment of parts of Beaver Creek Basin, Kentucky, 1955-59.** U.S. Geol. Surv. Prof. Pap. 427-B. 85 p., illus.

The preliminary results of investigation indicate that strip-mining for coal in the Beaver Creek Basin, Kentucky, has significantly changed the chemical quality of surface and groundwater, increased the sediment yield of the basin, altered the forest development, and has adversely affected the aquatic life of the stream.

**U.S.-KY : coal-B : IV**

108. Collier, C. R., R. J. Pickering, and J. J. Musser.

1970. **Influences of strip-mining on the hydrologic environment of parts of Beaver Creek Basin, Kentucky, 1955-66.** U.S. Geol. Surv. Prof. Pap. 427-C. 80 p., illus.

This report is third of a series on the environmental effects of strip-mining in Cane Branch Basin, McCreary County, Kentucky. It describes the results of the investigation from 1955 to 1966. Topics discussed: precipitation and runoff; groundwater; geochemistry of water; erosion and sedimentation; streambottom fauna; fish population; microbiology of streams; tree growth. Two maps attached.

See also: Mussner 1963 and Collier *et al*, 1964.

**U.S.-KY : coal-B : IV**

109. Collom, Robert H., Jr.

1971. **Dust control techniques useful in surface mining and related manufacturing.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 65-69. Ga. Surface Mined Land Use Board. Macon.

The State of Georgia is the largest producer of kaolin in the country. Manufacturing and processing of this material is troublesome. It is estimated that 80,000 tons per year is being emitted into the atmosphere. The collection of this fine dust is expensive but can be accomplished. A collection system can be paid for in a short time by recycling the dust.

**U.S.-GA : kaolin : V-A+VIII**

110. Contakos, James.

1962. **Restoration of areas affected by coal mining.** Nat. Symp. on Control of Coal Mine Drainage. Pa. Dep. Health Publ. 4: 48-52.

Describes the restoration of lands affected by coal mining as required by the Bituminous Coal Open Pit Mining Conservation Act of 1962.

**U.S.-PA : coal-B : VIII-A**

111. Cook, Larry.

1950. **New forests for Ohio.** Am. For. 56(11) : 6-8, 31, 34, illus.

Describes the reclamation program of strip-mined lands by the Ohio Reclamation Association.

**U.S.-OH : coal-B : VI**

112. Copeland, Otis L., and Paul E. Packer.

1972. **Land use aspects of the energy crisis and western mining.** J. For. 70: 671-675.

An overall picture of deposits and the present and potential mining of fuels and minerals in the interior West. Present and potential developments, land ownership, mineral rights and mining claims, and the challenges in preplanning and rehabilitation of stripped lands are discussed.

**U.S. : coal-L : VIII**

113. Corbett, Don M.

1968. **Ground-water hydrology pertaining to surface mining for coal—Southwestern Indiana.** Coal Mine Drain. Res. Symp. 2 Proc.: 164-189. Bitum. Coal Res., Inc., Monroeville, Pa.

The aquifers formed by surface mining reduce major flood flows and crests during wet periods, but increase flows during dry periods. Much of the water produced by the cast overburdens was captured by final cuts to form sizable lakes, and a large amount was retained in the overburden, replenishing annual losses by evaporation, seepage, and lake-outflow. Data on two Patoka River and three Busseron Creek tributaries (in Indiana) are discussed.

**U.S.-IN : coal-B : VI**

114. Corbitt, Robert A.

1971. **Design and operation of wastewater handling facilities.** Rehabil. Drastically Disturbed Surf. Mined Land Symp. Proc.: 70-73. Ga. Surface Mined Land Use Board. Macon.

In many areas of Georgia, muddy water is attributed to the surface mining industry. All waste waters must be treated to render them essentially free of suspended and settle-

able solids, and the pH should be in the range of 6.0 to 8.5. Engineering work to attain these goals is discussed.

**U.S.-GA : kaolin : VIII**

115. Cornwell, S. M., and E. L. Stone.
1968. **Availability of nitrogen to plants in acid coal mine spoils.** Nature 217: 768-769.

Highly acid anthracite black pyritiferous coal-mine spoils contain abundant available N for plant growth.

**U.S.-PA : coal-A : III-B**

116. Cornwell, Susan M., and Earl L. Stone.
1973. **Spoil type lithology and foliar composition of** *Betula populifolia.* *In* Ecology and Reclamation of Devastated Land vol. 1: 105-120. Gordon and Breach Sci. Publ., New York.

The availability of plant nutrients or possibly toxic elements to gray birch were assessed for five spoil types. Foliar concentrations of all elements except Cu differed significantly among spoil types, indicating that the lithological classification of spoils was meaningful in terms of plant uptake. Differences in N and P resulted from rock composition and weathering rate. Gray birch accumulated Zn to 400 ppm and Mn to 1,500 ppm without evidence of Zn, B, Al, or Mn toxicity.

**U.S.-PA : coal-A : III-B**

117. Cresswell, Christopher F.
1973. **Changes in vegetational composition, nutritional status, soils, and microbial populations with the establishment of vegetation on gold-mine dumps on the Witwatersrand.** *In* Ecology and Reclamation of Devastated Land vol. 2: 335-359. Gordon and Breach Sci. Publ., New York.

An account of the difficulties in establishing vegetation on gold mine dumps and the procedures adopted in establishing initial plant cover. The composition of the mine dump is discussed, and the nutrient requirements of the vegetation grown in pot culture using this media are considered. The effects of pH changes occurring due to the pyrite content are presented. Changes in microbial population with the establishment of vegetation are discussed.

**S. Africa : ore waste : III + VI-B**

118. Crowl, John M.
1962. **Reclamation of lands stripped by the opencut method of coal production.** Fifth World Forest. Congr. Proc. vol. 1: 611-615. Univ. Wash., Seattle.

A general discussion on strip-mining for coal and ore reclamation efforts and accomplishments by the industry and governmental agencies.

**U.S. : coal-B : VI**

119. Crowl, John M.
1965. **The Kentucky reclamation association.** Dep. Nat. Resour. Strip Mine Reclam. Symp. Proc.: 19-20. Frankfort.

Outlines the place of the Kentucky Reclamation Association in restoration of strip-mined lands. Revegetation efforts are described.

**U.S.-KY : coal-B : VI**

120. Croxton, W. C.
1928. **Revegetation of Illinois coal stripped lands.** Ecology 9: 155-175.

The vegetation of spoils is correlated with the acidity levels of the surface layer. It tends to become well established above pH 4.5 and fails below that point. There is little indication that the unproductivity of the bare areas is due to deficiency of nutrients. Plant succession on spoils of different acidity levels is discussed.

**U.S.-IL : coal-B : VI-B**

121. Culbertson, R. E., and Richard M. May.
1942. **Planting spoil banks and ditches.** Soil Conserv. 7 (10) : 260.

Revegetation of drainage ditches and spoil banks by direct seeding of grasses is suggested. Useful species are listed.

**U.S.-DE, MD : other : VI-B**

122. Cummins, David G., William T. Plass, and Claude E. Gentry.

1965. **Chemical and physical properties of spoil banks in eastern Kentucky coal fields.** USDA For. Serv. Res. Pap. CS-17. 12 p. Cent. States For. Exp. Stn., Columbus, Ohio.

It was found that 60 percent of the material that passed a 1-inch screen was less than 2 mm in size. The soil fraction of individual spoils was classified either as loam or clay loam. The samples were medium to extremely acid, with low concentrations of soluble salts and organic matter. Exchangeable Ca was low, but Mg was abundant. Available K and P were low to adequate for growth. Available Fe, Mn, and $SO_4$ were high at several locations.

**U.S.-KY : coal : III-B + C**

123. Cunningham, J. M.

1965. **The Pennsylvania strip-mine reclamation program.** Ky. Dep. Nat. Resour. Reclam. Symp. Proc.: 21-22. Frankfort.

Comments on Pennsylvania's strip-mine reclamation laws, their major provisions and implementation.

**U.S.-PA : coal-B : VIII-A**

124. Currier, W. F.

1973. **Basic principles of seed planting.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 225-232. Bitum. Coal Res., Inc., Monroeville, Pa.

The following basic principles and their application to seeding critical areas, including land disturbed by strip-mining, are discussed: the use of adapted species; reduction of plant competition; preparation of a good seedbed; covering the seed to proper depth; evenness of seed distribution; proper timing for seeding; and sufficient plant nutrients for plant establishment and growth. The use of two main methods of seeding — drilling and broadcasting — is related to these basic principles.

**U.S. : coal : VI-B**

125. Curtis, Willie R.

1967. **Hydrology.** Ky. Dep. Nat. Resour. Strip-Mining Symp. Proc. 3 p. Frankfort.

A general description of the influences of strip-mining on the water resource.

**U.S.-KY : coal-B : IV**

126. Curtis, Willie R.

1971. **Terraces reduce runoff and erosion on surface-mine benches.** J. Soil and Water Conserv. 26 (5): 198-199, illus.

Terraces can effectively control runoff and erosion on surface-mine benches. On a shale spoil peak, flow on a terraced plot was 65 percent less than on control plot; sediment yield was 52 percent less, and total runoff was 42 percent less. Comparable figures for plots on sandstone spoil were 65, 70, and 6 percent respectively.

**U.S.-KY : coal-B : IV-B + VI-A**

127. Curtis, Willie R.

1971. **Strip-mining erosion and sedimentation.** Am. Soc. Agric. Eng. Trans. 14 (3): 434-436, illus.

Six small watersheds in eastern Kentucky are being used to evaluate the effects of strip-mining for coal. Sediment yield is greatest during active mining and is directly related to the percentage of area disturbed. A heavily mined watershed yielded over 46,000 ppm of suspended sediment.

**U.S.-KY : coal-B : IV-E**

128. Curtis, Willie R.

1971. **Vegetating strip-mine spoils for runoff and erosion control.** W. Va. Univ. Symp. Reveg. and Econ. Use of Surf.-Mined Land and Mine Refuse Proc.: 40-41. Morgantown.

Excessive runoff and erosion are now considered among the most important adverse effects of surface mining, and reclamation objectives are being directed more toward control of these factors. An adequate cover of vegetation that is quickly established can be effective in runoff and erosion control. In some cases, mechanical means may be necessary for initial control while a vegetative

cover is being established for long-term control.

**U.S.-KY : coal-B : IV-E**

129. Curtis, Willie R.
1972. **Strip-mining increases flood potential of mountain watersheds.** Am. Water Res. Assoc. and Colo. State Univ. Nat. Symp. Watersheds in Transition Proc.: 357-360.

A study in eastern Kentucky indicated that surface mining for coal alters the natural processes and affects the water resources in small Appalachian watersheds. Peak flow rates increased by a factor of 3 to 5 after surface mining. Lag time was reduced, thus effecting an increase in the rate at which flood peaks move downstream. It appears that peak flow is directly and positively correlated with the percentage of area disturbed during surface mining.

**U.S.-KY : coal-B : IV**

130. Curtis, Willie R.
1972. **Chemical changes in streamflow following surface mining in Eastern Kentucky.** Coal Mine Drain. Res. Symp. 4 Proc.: 19-31. Bitum. Coal Res., Inc., Monroeville, Pa.

A study of the chemical quality of water in 6 small watersheds in Breathitt County, Ky., indicates that surface mining for coal may result in chemical pollution of the streams even in areas where acid is no problem. Among the elements showing greatest increases following mining are sulfate, Ca, and Mg. Al and Mn have increased, as have Fe and Zn. Some elements continue to increase at least up to 2 years after mining. Others peak rather quickly after the land disturbance and may soon return to pre-mining levels.

**U.S.-KY : coal-B : IV-F**

131. Curtis, Willie R.
1973. **Effects of strip-mining on the hydrology of small mountain watersheds in Appalachia.** *In* Ecology and Reclamation of Devastated Land vol. 1: 145-157. Gordon and Breach Sci. Publ., New York.

The effects of strip-mining on the water resources of small mountain watersheds were investigated in eastern Kentucky. Six subdrainages have been used to record pre-mining condition changes during active mining operations and the rate of recovery after mining. Stream turbidity and peak flows increase during mining, but on one subdrainage turbidity returned to near pre-mining conditions within 6 months after mining. Storm runoff durations apparently do not change. Sulfate and magnesium in the streamflow have increased since mining.

**U.S.-KY : coal-B : IV-C**

132. Curtis, Willie R.
1973. **Moisture and density relations on graded strip-mine spoils.** *In* Ecology and Reclamation of Devastated Land vol. 1: 135-144. Gordon and Breach Sci. Publ., New York.

A report on first-year results of a study to determine the disposition of subsurface moisture on leveled spoil banks in western Kentucky and to determine whether the moisture conditions can be changed through scarification and vegetative treatments. A significant difference was noted in density and available moisture between furrow ridge and valley locations. The lowest moisture values were noted in the surface foot. Surface scarification apparently has not affected moisture or density.

**U.S.-KY : coal-B : IV-B**

133. Curtis, Willie R., and William D. Cole.
1972. **Micro-topographic profile gage.** Agric. Eng. 53 (1) : 17.

Simple equipment has been designed and constructed to permit rapid measurements of the spoil surface. Data so gathered can be used to plot surface section profile useful in erosion studies.

**U.S.-KY : coal-B : IV**

134. Czapowskyj, Miroslaw M.
1969. **Anthracite coal-mine spoils today —forests tomorrow.** Pa. For. 59(3): 81-83.

A brief history of reclamation work in the Anthracite Region, summarizing the results of research conducted by the U.S. Forest Service.

**U.S.-PA : coal-A : VI-B**

135. Czapowskyj, Miroslaw M.
1970. **Experimental planting of 14 tree species on Pennsylvania's anthracite strip-mine spoils.** USDA For. Serv. Res. Pap. NE-155. 18 p., illus. Northeast For. Exp. Stn., Upper Darby, Pa.

Survival and height growth of 11 coniferous and 3 hardwood species were studied on four strip-mine spoil types in both graded and ungraded conditions. Hardwoods survived better and attained better heights than conifers. Hybrid poplar, NE-388, performed best. Almost all species performed better on graded spoils than on ungraded spoils. Selected physical and chemical characteristics of the strip-mine spoils are discussed.

**U.S.-PA : coal-A : III-B+C+VI**

136. Czapowskyj, Miroslaw M.
1973. **Establishing forest on surface-mined land as related to fertility and fertilization.** USDA For. Serv. Gen. Tech. Rep. NE-3: 132-139. Northeast. For. Exp. Stn., Upper Darby, Pa.

Most spoils are not hostile to planted trees. Nearly all essential elements for plant growth were found in the spoils; their concentrations depend on lithology, acidity, and the rate and degree of spoil weathering. Planted and seeded forest trees respond strongly to application of N and P, both singly and in combination. Certain spoils will respond to K application. Extreme acidity and high concentrations of Mn, Fe, Zn, and Al are major factors limiting plant growth on coal-breaker refuse; but such areas are a small portion of the total area of disturbed land. Application of lime alleviates these problems.

**U.S. : coal : III-B**

137. Czapowskyj, Miroslaw M.
1973. **Performance of red pine and Japanese larch planted on anthracite coal-breaker refuse.** *In* Ecology and Reclamation of Devastated Land vol. 2: 237-245. Gordon and Breach Sci. Publ., New York.

Red pine and Japanese larch seedlings were planted on coal-breaker refuse in Shamokin, Pennsylvania. The site consisted of highly acid slaty shales and coal fragments and soil-sized particles — 28 percent. Lime application was essential for adequate survival and establishment of both tree species; neither mulch nor fertilizer contributed substantially to tree establishment and growth. After 5 years the pH value of the surface layer showed neutral reaction in the limed plots.

**U.S.-PA : coal-A+R : VI-B**

138. Czapowskyj, Miroslaw M., and William E. McQuilkin.
1966. **Survival and early growth of planted forest trees on strip-mine spoils in the anthracite region.** USDA For. Serv. Res. Pap. NE-46. 29 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

A study of 6-year and older forest tree plantings on anthracite strip-mine spoils showed: (1) that average survival of all species was adequate; and (2) that the height growth was comparable to growth on natural soils of average productivity. A tentative spoil classification and a preliminary guide for tree planting were prepared.

**U.S.-PA : coal-A : III-A+VI-B**

139. Czapowskyj, Miroslaw M., John P. Mikulecky, and Edward A. Sowa.
1968. **Response of crownvetch planted on anthracite breaker refuse.** USDA For. Serv. Res. Note NE-78. 7 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Lime applications were essential to establishment of crownvetch on coal-breaker refuse in the Pennsylvania Anthracite Region, and mulch treatments were highly beneficial. Fertilizer applications had only slight effect on either establishment or growth.

**U.S.-PA : coal-A : VI-B**

140. Czapowskyj, Miroslaw M., and Edward A. Sowa.

1973. **Lime retention in anthracite coal-breaker refuse.** USDA For. Serv. Res. Note NE-154. 4 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Hydrated lime was applied to extremely acid anthracite coal-breaker refuse at rates of 2.5 and 5.0 tons per acre. The lime raised the pH to neutral range, and this range was still in evidence 7 years after treatment. The pH readings decreased with the depth of the refuse profile, and below 9 inches they approximated those of the control plots. The 2.5-tons-of-lime-per-acre treatment was almost as effective as the 5.0-ton treatment. Application of lime in establishing vegetation on coal-breaker refuse is recommended and encouraged.

**U.S.-PA : coal-A : VI-B**

141. Czapowskyj, Miroslaw M., and Ross Writer.

1970. **Hydroseeding on anthracite coal-mine spoils.** USDA For. Serv. Res. Note NE-124. 8 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Performance of selected species of legumes, grasses, and trees hydroseeded on anthracite coal-mine spoils in a slurry of lime, fertilizer, and mulch was evaluated. Hydroseeding failed on coal-breaker refuse, but was partially successful on strip-mine spoils.

**U.S.-PA : coal-A : VI-B**

142. Dale, Martin E.

1963. **Interplant alder to increase growth in strip-mine plantations.** USDA For. Serv. Res. Note CS-14. 4 p., illus. Cent. States For. Exp. Stn., Columbus, Ohio.

European alder is beneficial as a nurse crop to other tree species planted on strip-mined spoils. The nursing effect seemed to stimulate height growth, but had no effect upon survival.

**U.S.-KY : coal-B : VI-B**

143. Dalsted, Norman L., and F. Larry Leistritz.

1974. **A selected bibliography on coal-energy development of particular interest to the Western States.** ND Agric. Exp. Stn. Agric. Econ. Misc. Rep. 16. 82 p. Fargo.

This bibliography includes 486 citations on coal-energy development in coal-producing states, particularly in Montana, North Dakota, and Wyoming. The references are grouped under the following topics: (1) general references and bibliographies; (2) coal resources of the Western States; (3) demand for western coal; (4) surface coal mining; (5) spoil-bank reclamation; (6) mineral rights and public regulation of strip mining; (7) economic impact of strip-mining and power production; and (8) environmental impact of strip-mining and power production. The topic on spoil-bank reclamation lists 86 citations. Many references annotated.

**U.S.-MO, ND, WY : coal : VIII-E**

144. Darden, Sam.

1971. **The preparation and use of maps in reclamation work.** Rehabil. Drastically Surf. Mined Lands Symp. Proc.: 33-36. Ga. Surface Mined Land Use Board. Macon.

A brief description of the Georgia Surface Mined Land Use Board's requirements for land-use and reclamation maps. A map is a useful planning tool and essential to the rehabilitation of the site being mined.

**U.S.-GA : coal, kaolin : VIII**

145. Darmer, Gerhard.

1973. **Grasses and herbs for revegetating phytotoxic material.** *In* Ecology and Reclamation of Devastated Land vol. 2: 91-101. Gordon and Breach Sci. Publ., New York.

The overburden of Midgerman brown coal strip mines often contains marcasite ($FeS_2$). Extremely acid and toxic to plants, this component creates serious planting problems. After liming, seeding, and planting, these plants proved useful: *Phacelia tanacetifolia*

*Festuca* (spp)., *Lolfum italicum*, *Bromus inermis*, and *Phalaris arundinacea*. On level ground, grasses did well. On steep slopes, woody plants and grasses can be combined.

**Germany : coal-L : VI-B**

146. Davidson, Walter H.
1970. **Deer prefer pine seedlings growing near black locust.** USDA For. Serv. Res. Note NE-111. 4 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Volunteer black locust on coal spoils appeared to make some species of pine seedlings more palatable to white-tailed deer. The nitrogen produced by the black locust may have caused more succulent tissue growth in the pines.

**U.S.-PA : coal-B : VII-E**

147. Davidson, Walter H., and Grant Davis.
1972. **Sprouting of thinned hybrid poplars on bituminous strip-mine spoils in Pennsylvania.** USDA For. Serv. Res. Note NE-147. 6 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

Five-year-old hybrid poplar stands were thinned, using basal sprays, cutting, and stump spraying or simply cutting. Results indicate that hybrid poplar can be successfully regenerated under coppice management or can be easily removed for stand conversion.

**U.S.-PA : coal-B : VII-D**

148. Davidson, Walter H., and Edward A. Sowa.
[In press] **Container-grown seedlings show potential for afforestation of Pennsylvania coal-mine spoils.** Tree Planters' Notes.

Afforestation attempts with Ontario-type tubelings indicated that frost-heaving can be extremely detrimental on coal-mine spoils. Other types of containers — peat pots and Jiffy 7's — were found to be more resistant to frost-heaving. Compared with bare-root seedlings, seeded red pines in these containers survived and grew equally well.

**U.S.-PA : coal : VI-B**

149. Davis, Grant.
1964. **Second-year results of hybrid poplar test plantings on bituminous strip-mine spoils in Pennsylvania.** USDA For. Serv. Res. Note NE-19. 7 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

A broad screening test was designed to determine the suitability of 60 clones of hybrid poplar for strip-mine plantings. Two-year results revealed great variability among the six planting sites, apparently related to differences in spoil acidity. Certain clones will be suitable for planting all but the most acid spoils.

**U.S.-PA : coal-B : VI-B**

150. Davis, Grant.
1965. **The cooperative research program in Pennsylvania.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 55-63. University Park.

The author describes the genesis of the Research Committee on Coal Mine Spoil Revegetation in Pennsylvania and how it is developing and conducting its research program. Research results and application in both the bituminous and the anthracite regions are reviewed.

**U.S.-PA : coal : VIII-C**

151. Davis, Grant.
1967. **Hydrology of contour strip-mines in the Appalachian region of the United States.** IUFRO Congr. 14 Proc. vol. 1, Sect. 11: 420-443, illus.

Contour strip-mining may have profound effects on streamflow, sediment load, and water quality of streams in a watershed. The degree of impact depends upon the proportion of area mined, hydrologic characteristics of the spoil material, and topography of the watershed. Because mining is extensive and subject to little experimental control, the multi-watershed approach offers hydrologic effects of such mining.

**U.S.-KY, WV : coal-B : IV**

152. Davis, Grant.
1973. **Comparison of fall and spring**

**planting on strip-mine spoils in the bituminous region of Pennsylvania.** *In* Ecology and Reclamation of Devastated Land vol. 1: 525-538. Gordon and Breach Sci. Publ., New York.

In 1961 a study was initiated to evaluate the relative success of fall versus spring planting of ten coniferous tree species and five hardwood shrub species on strip-mine spoils. Planting extended over a 2-year period and included tree planting dates in each season. In general, initial tree survival was better with spring planting than with fall planting, especially on the more acid sites. The shrubs survived well with both spring and fall planting on the better sites.

**U.S.-PA : coal-B : VI-B**

153. Davis, Grant, and Walter H. Davidson.
1968. **Coal-mine spoil banks offer good potential for timber and wildlife production.** Pa. For. 58 (1): 20-21, illus.

Lands strip-mined for coal are accessible and will grow a variety of trees, shrubs, and herbaceous species. Conifers and hybrid poplars are the best choices for pulp and timber. Plantings for game food and cover can be incorporated into reclamation plans.

**U.S.-PA : coal-B : VII-D**

154. Davis, Grant, and Rex E. Melton.
1962. **Plantations on strip-mine banks can yield timber products.** Pa. State Univ. For. Sch. Res. Pap. 29. 2 p.

An examination of ten 25-year-old plantations in the bituminous region of Pennsylvania showed that Scotch pine, Japanese larch, and white pine are potentially good timber producers on strip-mine banks. Eight other species in the study should produce some timber.

**U.S.-PA : coal-B : VII-D**

155. Davis, Grant, and Rex E. Melton.
1963. **Trees for graded strip-mine spoils.** Pa. State Univ. For. Sch. Res. Pap. 32. 4 p. University Park.

The results of a survey on performance ratings at 7 years of 10 coniferous and 5 hardwood species planted on graded bituminous spoils associated with coal seams. Better performance was observed on spoils associated with the Brookville, Upper and Lower Freeport, and Pittsburgh seams. Spoils from the Clarion and Lower and Middle Kittanning seams were less favorable. Japanese larch, Banks pine, and Scotch pine were the best conifers; black locust was best among hardwoods.

**U.S.-PA : coal-B : VI-B**

156. Davis, Grant, W. W. Ward, and R. D. McDermott, Editors.
1965. **Coal Mine Spoil Symposium Proceedings.** Pa. State Univ. Sch. Forest. Resour. 141 p. University Park.

This volume contains 21 papers presented at the symposium held at Pennsylvania State University in October 1965. The theme of the symposium was "Scientific Planning for Regional Beauty and Prosperity". Topics discussed were: national implications, legislative and regulatory considerations, engineering and site characteristics, and revegetation objectives and methods.

**U.S. : coal-B : VIII-D**

157. Davis, Joseph R., and Beecher J. Hines.
1973. **Debris basin capacity needs based on measured sediment accumulation from strip-mined areas in eastern Kentucky.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 260-276. Bitum. Coal Res., Inc., Monroeville, Pa.

Legislation has been passed in Kentucky requiring surface miners to store, catch, or trap the sediment carried by runoff from strip-mined lands. To aid in being able to project sediment yield so that adequate storage basins could be built, the Soil Conservation Service measured accumulations in some sediment debris basins less than 1 year old. The results indicated that sediment yield of 0.28 acre-feet per acre of disturbed land could be expected for a 3-year design period. It was assumed, based on research experience, that in 3 years a vegetative cover could be developed that would effectively control erosion.

The engineering standard for basin construction, developed by the Soil Conservation Service, is appended.

**U.S.-KY : coal-B : IV-H**

158. Dean, F. W.
1925. **The reclamation of stripped coal lands.** J. For. 23: 677-682.

A summary of the reclamation work on strip-mined lands accomplished by the Wayne Coal Co. The cost of tree planting was about $7.5 per acre. Remarkable growth of black locust was observed. Other species — pines, black walnut and yellow poplar — have shown little or no growth.

**U.S.-OH : coal-B : VI-B**

159. Dean, Karl C.
1971. **Potential productive use of lands affected by the mineral industry.** Rehabil. Drastically Disturbed Surf. Mined Lands. Symp. Proc.: 22-27. Ga. Surface Mined Land Use Board. Macon.

Mining and milling wastes affect extensive acreages of land in this country. These lands offer potential for productive uses. The excavated areas may be used for recreation or agriculture, or as containers for various wastes. Processing wastes may be used as raw materials for structural products or artificial soils.

**U.S. : coal, other : VIII**

160. Dean, Karl C., and Richard Havens.
1972. **Stabilization of problem mineral wastes.** U.S. Bur. Mines Salt Lake City Metall. Res. Cent. 15 p.

The authors summarize effective procedures for vegetating average tailings and the cost differential between the various methods, and also suggest procedures that may be applicable for stabilization of pyrite-containing wastes. The use of buried layers of sewage sludge is discussed.

**U.S. : ore waste : VIII-B**

161. Dean, Karl C., and Richard Havens.
1972. **Reclamation of mineral milling wastes.** U.S. Bur. Mines Salt Lake City Metall. Res. Cent. 7 p.

Chemical, vegetative, and combined chemical-vegetative procedures for stabilizing milling wastes are discussed. Costs of achieving reclamation using these procedures are compared with those of other physical and vegetative approaches. Chemical-vegetative procedure for establishing vegetation directly on fine-sized wastes compares favorably with other stabilization processes.

**U.S.-UT : ore waste : VI-B**

162. Dean, Karl C., and Richard Havens.
1973. **Methods and costs for stabilizing tailings ponds.** U.S. Bur. Mines Salt Lake City Metall. Res. Cent. 15 p.

This report summarizes effective procedures developed by the Federal Bureau of Mines for vegetating average tailings, the cost differential between various methods, and procedures that may be applicable for achieving stabilization of pyrite containing wastes. The use of buried layers of sewage sludge to prevent acidification is discussed.

**U.S.-UT : ore waste : VI**

163. Dean, Karl C., Richard Havens, and Kimball T. Harper.
1969. **Chemical and vegetative stabilization of a Nevada copper porphyry mill tailing.** U.S. Bur. Mines Rep. Invest. 7261. 14 p., illus.

Tests were made on stabilizing windblown tailings at McGille, Nevada. Legumes, winter wheat, wheatgrasses, and wild rye were seeded and protected with a resinous adhesive chemical until sprouting. Annual precipitation is about 8 inches; strong winds are common. The tailings were slightly basic (pH 7.3 to 7.5). Fertilizer was used; no irrigation. Costs were estimated at about $135 per acre and probably could be reduced.

**U.S.-NV : ore waste : VI**

164. Dean, K. C., R. Havens, K. T. Harper, and J. B. Rosenbaum.
1973. **Vegetative stabilization of mill mineral wastes.** *In* Ecology and Recla-

mation of Devastated Land vol. 2: 119-136. Gordon and Breach Sci. Publ., New York.

Physical, chemical, vegetative, and combination methods of stabilizing fine wastes have been developed. Major research emphasis has been directed toward developing vegetative and combined chemical-vegetative stabilization procedures. A resinous adhesive compound used in conjunction with selected vegetation seems to be exceptionally effective for achieving stabilization. Application of this procedure effectively stabilized the fine sands of copper tailings against wind erosion.

**U.S. : ore waste : VI**

165. Dean, Karl C., Richard Havens, and E. G. Valdez.

1969. **Utilization and stabilization of solid mineral wastes.** U.S. Bur. Mines Salt Lake City Metall. Res. Cent. 21 p.

Possible uses for solid metallic and nonmetallic wastes from mines, mills, and smelters are reviewed. Stabilization techniques by using the physical, chemical, vegetative, and combined methods are discussed; and the advantages and problems are pointed out. Revegetative research, including the deleterious effects of salts and heavy metals, is reviewed. Interactions of fertilizers with heavy metals, physical and chemical modifications, and dewatering effects were studied in detail. Combination tests of chemical and vegetative stabilization are described.

**U.S. : ore waste : VI**

166. Deely, Daniel J., and F. Yates Borden.

1969. **High surface temperatures on strip-mine spoils.** Pa. State Univ. Res. Briefs 4 (2) : 15-17.

Surface temperatures were measured on dry spoil materials ranging from light sandstones to dark bituminous coal. Maximum temperatures reached 50 to 55°C on the lighter materials and 65 to 70°C on the darkest materials. Results indicate that heat injury to planted seedlings is possible on all bituminous spoils, but on the black materials the threat is especially serious.

**U.S.-PA : coal-B : III-C**

167. Deely, Daniel J., and F. Yates Borden.

1973. **High surface temperatures on strip-mine spoils.** *In* Ecology and Reclamation of Devastated Land vol. 1: 69-79. Gordon and Breach Sci. Publ., New York.

Surface temperatures of strip-mine spoil material consistently reached 50 to 55°C on the lightest colored materials, and 65 to 70°C on the darkest materials. The average temperature difference observed between the lightest and the darkest spoil materials was approximately 15°C. Spoil materials that underwent the largest decreases in surface moisture content experienced the greatest rises in surface temperature following rain, maximum surface temperatures generally increasing at an average rate of 2 to 4°C per day for the first 6 to 10 days after rain. The surface temperatures recorded indicated that heat injury to plant seedlings is a very real possibility on spoil materials, and especially on the black material.

**U.S.-PA : coal-B : III-C**

168. Deely, Daniel J., Orville R. Russell, and Frank J. Wobber.

1973. **Applications of aerial and orbital remote sensing to the study of mined lands.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 15-25. Bitum. Coal Res., Inc., Monroeville, Pa.

Various kinds of remote-sensing imagery have been investigated for their ability to provide information about mining operations and their usefulness in monitoring reclamation. The use of black and white low-altitude photography is well known and is often used for field reference maps and recording baseline and operating conditions. Earth Resources Technology Satellite imagery, which records in four spectral bands, distinguishes vegetation from bare land and can identify bodies of water 100 feet at the narrowest dimension. The advantage of ERTS imagery is repetitive coverage, which

shows continuing changes such as seasonal effects on vegetation and moisture. High-altitude aerial photography gives more detail and is more accurate than ERTS imagery. Color infrared film is considered at present to be best for the majority of uses.

**U.S.-PA : coal-B : I-B**

169. Deitschman, Glenn H.
1950. **Comparative survival and growth of trees planted under three types of overhead cover on strip-mined land in southern Illinois.** USDA For. Serv. Cent. States For. Exp. Stn. Note 63. 2 p. Columbus, Ohio.

Beneficial effects of cover upon the early development of underplanted species—fairly tolerant to shading—were demonstrated.

**U.S.-IL : coal-B : VI-B**

170. Deitschman, Glenn H.
1950. **Seedling survival and height growth on graded and ungraded strip-mined land in southern Illinois.** USDA For. Serv. Cent. States For. Exp. Stn. Note 62. 2 p., illus. Columbus, Ohio.

Tree plantings were made to compare survival and height growth on graded versus ungraded spoils. The grading did not affect survival, but growth was better on ungraded spoils.

**U.S.-IL : coal-B : VI-B**

171. Deitschman, Glenn H.
1956. **Growth of underplanted hardwoods in black locust and shortleaf pine plantations.** USDA For. Serv. Cent. States For. Exp. Stn. Note 94. 2 p. Columbus, Ohio.

Native hardwoods planted under black locust were taller than those planted under shortleaf pine. Early results are presented.

**U.S.-IL, IN : coal-B : VI-B**

172. Deitschman, Glenn H., and Richard D. Lane.
1952. **Forest planting possibilities on Indiana coal-stripped lands.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 131. 57 p., illus. Columbus, Ohio.

This survey report lists and describes the extent and major conditions on Indiana coal-stripped lands that affect forest plantings and presents tentative forest-planting guides and recommendations for the more important bank types and conditions. Recommendations are based upon a reconnaissance of strip-mined lands, an examination of older plantings and natural forest, and the results of forest planting experiments. The work is beneficial in evaluating site factors on stripped lands for future plantings.

**U.S.-IN : coal-B : III+VII-D**

173. Deitschman, Glenn H., and J. W. Neckers.
1953. **Identification and occurrence of sulfides on land stripped for coal.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 136. 21 p., illus. Columbus, Ohio.

A field test for estimating the concentration of sulfides in overburden materials is reported. Results obtained by the test correlated with laboratory analyses for total S. Sulfides were found to be highest in dark carbonaceous spoils and in strata laying near coal seams. Prediction of mine-bank acidity has to be based on sulfide content, initial pH, and physical properties of spoil.

**U.S.-IL, IN : coal-B : III**

174. DenUyl, Daniel.
1962. **Survival and growth of hardwood plantations on strip mine spoil banks of Indiana.** J. For. 60: 603-606.

Eleven growing seasons is not enough time to determine suitability of certain hardwood species for extensive plantings. Only cottonwood reached crop-tree size. Longer periods of time and more carefully controlled experiments are needed before species selection can be done with certainty.

**U.S.-IN : coal-B : VI-B**

175. Despard, Thomas L.
1974. **Avoid problem spoils through overburden analysis.** USDA For. Serv. Gen. Tech. Rep. NE-10. 4 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

Indiscriminate placement of toxic overburden at the spoil surface creates reclamation problems. Evaluation of material before mining has begun is suggested. This can be done by core-drilling the area and analyzing the core samples for toxic strata. Mining plans can be devised that will insure burial of such material.

**U.S.-KY : coal-B : III**

176. Deul, Maurice.
1968. **Turbidity measurements as an indicator of solids content of neutralized mine water.** Coal Mine Drain. Res. Symp. 2 Proc.: 35-38. Bitum. Coal Res., Inc., Monroeville, Pa.

Turbidity measurements are accurate indicators of suspended solids content only for a narrow range of sizes and solids composition. For acid mine waters neutralized with lime or limestone, the suspended solids content, as estimated by a Jackson candle turbidity apparatus, diverges greatly from the actual solids content determined gravimetrically. The experimental results show that turbidity measurements do not give an accurate estimate of the concentration of suspended solids in neutralized mine water effluent.

**U.S. : coal-B : IV-E**

177. Dickerson, John A., and W. E. Sopper.
1973. **The effect of irrigation with municipal sewage effluent and sludge on selected trees, grasses and legumes planted in bituminous strip mine spoil.** Pa. State Univ. Sch. For. Res. Res. Briefs 7 (1) : 1-4.

Municipal sludge and sewage effllluent can be used to ameliorate harsh site conditions found on bituminous spoil banks.

**U.S.-PA : coal-B : VI-B**

178. Dickman, Irving J.
1964. **The strip-mine reclamation program in Ohio.** Ohio J. Sci. 64 (2) : 165-168.

Discusses the provisions of the Strip Coal Mining Act of 1948 and the requirements of the new and amended laws passed in 1949, 1955, and 1959. The factors affecting mining and the ultimate use of reclaimed lands are outlined.

**U.S.-OH : coal-B : VIII-A**

179. Dietrich, I. T.
1973. **An historical overview of strip mine reclamation in North Dakota.** *In* Some environmental aspects of strip mining in North Dakota. N.D. Geol. Surv. Educ. Ser. 5: 49-51.

Success in revegetation has been variable. Leveling and placing topsoil adds greatly in revegetation of spoil area.

**U.S.-ND : coal-L : VI-B**

180. Bravkovic, Dragoljub.
1973. **Reclamation methods to prevent water pollution in the Morava River Watershed.** *In* Ecology and Reclamation of Devastated Land vol. 2: 361-378. Gordon and Breach Sci. Publ., New York.

Damages caused by sediments from eroded lands and mined areas in the Morava Watershed in Serbia are discussed. Slope terracing and establishment of vegetative cover were effective in achieving stabilization, reducing pollution problems, and minimizing sediment loads. Plant species used are listed. Discussion on economic evaluation of the problem.

**Yugoslavia : coal, other : IV-E+VI-B**

181. Eck, H. V., R. F. Dudley, R. H. Ford, and G. W. Gnatt, Jr.
1968. **Sand dune stabilization along streams in the southern Great Plains.** J. Soil and Water Conserv. 23 (4) : 131-134.

Although basic principles apply to sand dune stabilization everywhere, the exact procedure followed and materials used may have to be altered somewhat to achieve dune stability in a specific location. Procedures followed, plant materials, fertilizers, and mulches used in the stabilization of sand dunes are discussed.

**U.S.-TX, OK : sand and gravel : VI-A**

182. Edmunds, William E.
1972. **Coal reserves of Pennsylvania:**

**total, recoverable, and stripable (January 1, 1970).** Pa. Dep. Environ. Resour. Bur. Topog. and Geol. Surv. Inf. Circ. 72. 35 p.

Data on coal reserves in both bituminous and anthracite coal fields. Estimates on Pennsylvania's readily minable, recordable reserves are: deep mining 8 to 9 billion tons, strip-mining 1 billion tons. At the present rate of mining, these reserves represent about 50 years of strip mining and 150 years of deep mining.

**U.S.-PA : coal : I-A**

183. Edgerton, Barry R., and W. E. Sopper. 1974. **The effects of municipal sewage effluent and liquid digested sludge on the establishment of grasses and legumes on bituminous coal strip-mine spoils.** PA. State Univ. Coll. Agric. Exp. Stn. Res. Briefs 8(1) : 6-9.

Treated effluent and sludge irrigation makes possible the establishment and growth of grasses and legumes on highly acid strip-mine spoils. They supply valuable nutrients, increase pH, and decrease the concentrations of toxic metals.

**U.S.-PA : coal-B : VI-B**

184. Einspahr, Dean William. 1956. **Coal spoil-bank materials as a medium for plant growth.** Iowa State Coll. J. Sci. 30 (3) : 352-353.

Abstract of a Ph.D. thesis, characterizing Iowa coal mine spoils as a medium for plant growth.

**U.S.-IA : coal-B : III+VI-B**

185. Emrich, Grover H., and Gary L. Merritt. 1969. **Effects of mine drainage on ground water.** Ground Water 7 (3) : 27-32.

Acid mine drainage adversely affects the groundwater quality. It increases the iron and sulfate content, particularly in the vicinity of strip mines.

**U.S. : coal : IV**

186. Engineering and Mining Journal. 1961. **Cyanamid reclaims land as it mines in Florida's phosphate fields.** Eng. and Min. J. 162 (12) : 99.

Reclamation of mined lands by Cyanamid Company is carried out simultaneously with mining.

**U.S.-FL : phosphates : VI**

187. Errington, J. C., and Jack V. Thirgood. 1971. **Anyox smelter fumes long gone revegetation now under study.** N. Miner Annu. Rev. 5 p., illus.

Preliminary report on the extent of destruction of vegetation due to smelter fumes during the early years of this century in the vicinity of Anyox, British Columbia, and subsequent recovery of vegetation half a century later.

**Canada-BC : other : V-A+VI-B**

188. Eshbaugh, Fred P. 1949. **The place of research in relation to certain phases of strip-land reclamation in Kansas.** Kans. Acad. Sci. Trans. 52 (2) : 149-159.

The author discusses the development of spoil-reclamation research conducted by the U.S. Forest Service. Examples of studies in progress, information gained, and the areas of needed research are pointed out. An operational plan of research supported by mining industries and state and federal governments is suggested. The necessity of effective reclamation laws and an active program for strip-mine reclamation in Kansas are pointed out.

**U.S.-KS, MO, OK : coal, other : VIII-C**

189. Feiss, Julian W. 1965. **The national strip mine study.** Ky Dep. Nat. Resour. Strip Mine Reclam Symp. Proc.: 28-30. Frankfort.

Briefing on strip-mining for coal and other commodities and reclamation problems on a nationwide scale.

**U.S. : coal : VIII-A**

190. Feiss, Julian W.
1965. **Coal mine spoil reclamation, scientific planning for regional beauty and prosperity, national implications—scientific planning.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 12-23. University Park.

A discussion of the subject related to the total environment, in the prespective of the world, national, and coal-mining problems. The need of a land ethic, an understanding of man's relationship to the earth, water, and the air that we breathe is strongly emphasized.

**U.S. : coal : VIII**

191. Fenton, M. Robert.
1973. **Landscape design principles for strip-mine restoration.** *In* Ecology and Reclamation of Devastated Land vol. 2: 485-495. Gordon and Breach Sci. Publ., New York.

The Moraine State Park in western Pennsylvania contained areas that had previously been strip-mined. These areas had to be reclaimed so that they would blend in with the surrounding unmined areas. Grading, drainage control, and planting of vegetation were used to reduce pollution and to enhance the scenic values of the park. Design principles such as spatical characteristics, land forms, type and arrangement of vegetation, and location of walks and overlooks were considered in the overall plan. Actual reclamation was done on a work-unit basis, but the units were arranged in sequence to provide a continuous experience for the park visitor.

**U.S.-PA : coal-B : VI**

192. Finn, Raymond F.
1952. **The nutrient content of leaves and tree growth as affected by grading on three strip-mined areas.** USDA For. Serv. Cent. States For. Exp. Stn. Stn. Note 70. 2 p., illus. Columbus, Ohio.

White ash and yellow-poplar grew equally well on graded and ungraded spoils derived from sandstones and shales. Growth was significantly better on ungraded spoils derived from limestone. No marked differences in foliar N, P, and Cu between graded and ungraded spoils were noted.

**U.S.-OH : coal-B : VI-B**

193. Finn, Raymond F.
1953. **Foliar nitrogen and growth of certain mixed and pure forest plantings.** J. For. 51: 31-33.

Foliar N and the growth of certain forest species were compared in various covers. Some species showed greater heights and foliar N when associated with tree covers on old fields or bare spoils. Black locust was superior cover. Yellow-poplar, black walnut, and black cherry made the greatest response to improved N provided by black locust.

**U.S.-OH : coal-B : VI-B**

194. Finn, Raymond F.
1958. **Ten years of strip-mine forestation research in Ohio.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 153. 38 p., illus. Columbus, Ohio.

Ten-year results of tree-planting studies conducted on coal-mine spoils in southeastern Ohio are summarized. Species adaptation, mixed plantings, direct seeding, planting methods, and effect of spoil grading are discussed.

**U.S.-OH : coal-B : VI-B**

195. Fisher, Wilson.
1972. **Airborne infrared detection and mapping of coal mine drainage.** Coal Mine Drain. Res. Symp. 4 Proc.: 331-339. Bitum. Coal Res., Inc., Monroeville, Pa.

Airborne infrared (IR) imaging systems were used to detect and map acid mine water and fresh water sources and their drainageways. Seasonal experiments over a subwatershed illustrate the utility of this approach in establishing the relative quantity of acid mine water with seasonal hydrologic change. Although the method does not discriminate between acid water and fresh water, most of the acid water sources are recognized by as-

sociation with deep-mine or strip-mine features.

**U.S. : coal : I-B+IV**

196. Foreman, John W.
1972. **Evaluation of mine sealing in Butler County, Pennsylvania.** Coal Mine Drain. Res. Symp. 4 Proc.: 83-95. Bitum. Coal Res., Inc., Monroeville, Pa.

Two projects on deep-mine sealing are discussed. On the basis of this experience it is reasonable to anticipate that, while the success of individual seals may vary widely, the overall effect of a deep-mine sealing project will reduce acid loadings by more than 60 percent. Some cost figures are given.

**U.S.-PA : coal-B : VI**

197. Foreman, John W., and Earl G. Tarr.
1968. **Moraine State Park mine drainage project.** Coal Mine Drain. Res. Symp. 2 Proc.: 246-254. Bitum. Coal Res., Inc., Monroeville, Pa.

Describes the work under way on 16,000-acre demonstration area known as Moraine State Park, for rehabilitation of coal-mined lands in Pennsylvania.

**U.S.-PA : coal-B : VI**

198. Foresman, Frank J.
1952. **Stripped land rehabilitation.** Am. Min. Congr. Coal Mine Mod. Year. 7 p.

Describes how strip pits have been converted into forest, farming and pasture lands, and recreational areas.

**U.S.-KS : coal-B : VII**

199. Fowler, Dale K., and Charles H. Peery, III.
1973. **Three years' development of a public use wildlife area on a mountain coal surface mine in southwest Virginia.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 319-333. Bitum. Coal Res., Inc., Monroeville, Pa.

The 9,760-acre Hagy Wildlife Management Area was established in Wise County, Va. The purpose was to demonstrate that coal-mine spoil could be developed as an integral portion of a public-use wildlife area. Cooperating agencies were: Penn Virginia Corp., Virginia Division of Mined Land Reclamation; Virginia Commission of Game and Inland Fisheries, and TVA. The terms of cooperative agreement, and the function and responsibilities of the cooperators are described; and the early results of reclamation and the technique used are discussed.

**U.S.-VA : coal-B : VII-E**

200. Fox, Alfred C.
1971. **Development and impoundment of drastically disturbed surface mined lands for fishing.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 109-111. Ga. Surface Mined Land Use Board. Macon.

Development of surface-mined lands for fisheries use is a widely utilized method of useful reclamation. Methods for impoundment management on surface-mined lands will have to be improved considerably before the use of these areas can be maximized. Very little work has been done in Georgia to evaluate impoundment management in kaolin mining areas.

**U.S.-GA : coal, other : VII-G**

201. Francis, James M.
1973. **Stabilizing iron-ore tailings with vegetation.** *In* Ecology and Reclamation of Devastated Land vol. 2: 451-455. Gordon and Breach Sci. Publ., New York.

An area of 200 acres of iron ore mine waste was successfully planted with grasses, shrubs, and trees. A 7-year report.

**U.S.-PA : ore waste : VI-B**

202. Frank, Robert M.
1964. **A guide for screen and cover planting of trees on anthracite mine-spoil areas.** USDA For. Serv. Res. Pap. NE-22. 50 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Areas disturbed by coal mining were mapped and classified according to kind of spoil, density of natural tree cover, and visibility. Potential sites for screen and cover plantings

were delineated, and the number of tree seedlings needed for planting programs was estimated.

**U.S.-PA : coal-A : III-A+VI-B+VII-A**

203. Frawley, Margaret L.
1971. **Surface mined areas; control and reclamation of environmental damage.** U.S. Dept. Inter. Bibliogr. Ser. 27. 63 p.

This bibliography lists 387 references about soil shifts, chemical modification, and water pollution resulting from surface mining and the restoration of mined areas. Only material published in the United States during the period from June 1960 to June 1970 is included. The material is arranged in four categories: (1) general, (2) environmental effects, (3) protective measures and (4) reclamation. Name and subject indexes are included.

**U.S. : coal : VIII-E**

204. Freese, Frank.
1954. **Tree species for planting spoil banks in North Alabama.** Tree Planters' Notes 17: 15-18.

Sycamore and loblolly pine are the most promising species for the afforestation of spoil banks in North Alabama. The gain from fertilizing is too slight to justify the effort. A lack of spoil stability contributed to the failure of direct seeding of pines.

**U.S.-AL : coal-B : VI-B**

205. Funk, David T.
1962. **A revised bibliography of strip-mine reclamation.** USDA For. Serv. Cent. States For. Exp. Stn. Misc. Release 35. 20 p. Columbus, Ohio.

A list of nearly 100 references on strip-mine reclamation published since 1953 when Limstrom's original bibliography was issued, plus more than 70 technical citations that appeared in the original.

**U.S. : coal : VIII-E**

206. Funk, David T.
1963. **Hybrid poplars on Ohio spoil banks.** USDA For. Serv. Res. Note CS-8. 4 p. Cent. States For. Exp. Stn. Columbus, Ohio.

Fourteen selected clones of hybrid poplars survived better and grew faster on Sewickley-spoils derived from shales and sandstones than on Pittsburgh spoils derived from limestone and clay. The growth differences (after 10 years) seem to reflect spoils physical characteristics which were more favorable on Pittsburgh sites. Partial grass and herb cover apparently had a depressing effect on hybrid poplar growth. Among the best parents were: *P. deltoides, P. maximowiczii, P. nigra,* and some of its cultivars.

**U.S.-OH : coal-B : VI-B**

207. Funk, David T.
1973. **Growth and development of alder plantings on Ohio strip-mine banks.** *In* Ecology and Reclamation of Devastated Land vol. 1: 483-491. Gordon and Breach Sci. Publ., New York.

European alder plantations containing several seed sources performed well on strip-mined areas with pH ranging from 4 to 5. After 7 years, trees from southern Germany were larger than those of northern Germany, Belgium, Denmark, or Sweden. All seed sources grew better on lower slopes than on upper slopes. *Alnus glutinosa* should be suited for use as nitrogen-fixing nurse tree; other alder species may be useful for pulpwood production.

**U.S.-OH : coal-B : VI-B**

208. Funk, David T., and Martin E. Dale.
1961. **European alder: a promising tree for strip-mine planting.** USDA For. Serv. Cent. States For. Exp. Stn. Stn. Note 151. 2 p. Columbus, Ohio.

European alder looks like a valuable nurse species for planting on extremely acid strip-mine spoils.

**U.S.-KY, OH : coal-B : VI-B**

209. Funk, David T., and Rodney H. Krause.
1965. **Fertilizing strip-mine plantings**

**benefits some hardwoods.** Tree Planters' Notes 71: 21-22.

Plantings on graded strip-mined lands in Ohio were fertilized with ⅓-ounce high N fertilizer pellets. Early results showed reduced survival, but total heights of fertilized American sycamore, European alder, yellow-poplar, and red oak were significantly greater than those of unfertilized trees.

**U.S.-OH : coal-B : VI-B**

210. Gadgil, Ruth L.
1969. **Tolerance of heavy metals and the reclamation of industrial waste.** J. Appl. Ecol. 6: 247-259.

The Zn or Cu tolerance of grasses growing on mine spoils was tested, and the results were compared with growth on slag tips. The mine-spoil plants were more tolerant to Cu or Zn than those found on slag tips or on uncontaminated soil. Statistical comparisons were made. Factors other than toxicity of a single heavy metal seem to limit plant growth. A drip-culture apparatus, suitable for use in solution tests, is described.

**Great Britain : ore waste : III-B+VI-B**

211. Georgia Surface Mined Land Use Board.
1971. **First symposium on the Rehabilitation of Drastically Disturbed Surface Mined Lands.** 126 p. Macon, Ga.

A collection of papers presented at the symposium by individuals representing universities, industries, and various levels of government. A wide range of reclamation and rehabilitation subjects are discussed.

**U.S.-GA : kaolin : VIII-D**

212. Geyer, Wayne A.
1971. **Reforesting Kansas coal spoils.** Kans. State Univ. Agric. Exp. Stn. Circ. 399. 10 p., illus. Manhattan.

Burr oak, sycamore, cottonwood, loblolly pine, and shortleaf pines are the promising species. Other pines are difficult to establish. Black walnut should be used sparingly in plantings. Spoil grading restricts tree growth.

**U.S.-KS : coal-B : VII-D**

213. Geyer, Wayne A.
1972. **Timber growth on graded and ungraded strip-mine spoil banks in southeast Kansas.** Kans. Acad. Sci. Trans. 74 (3 and 4): 318-324, illus.

Twenty-two years of growth and development of 13 forest species on graded and ungraded spoils are described. The grading of fine-textured spoils adversely affected the performance of trees. Spoil-grading concept is discussed.

**U.S.-KS : coal-B : VII-D**

214. Geyer, Wayne A.
1972. **Mined land potential for raising timber crops.** Univ. Kans. State Geol. Surv. Spec. Distrib. Publ. 65: 18-21. (1972 Mined Land Workshop Proc.)

Raising timber on coal spoils should be considered for two land forms: (1) unleveled land with established woody vegetation and (2) recently graded lands. Trees grown on unleveled lands produce cottonwood, pulpwood, firewood, charcoal wood, and sawtimber. On recently graded lands, short-term crops—cottonwood, pulpwood, southern pine posts, and Christmas trees — can be grown; and combination nut-log-grazing programs show promise.

**U.S.-KS : coal-B : VII-D**

215. Geyer, Wayne A.
1973. **Tree species performance on Kansas coal spoils.** *In* Ecology and Reclamation of Devastated Land vol. 2: 81-90. Gordon and Breach Sci. Publ., New York.

An evaluation of survival and growth of 22-year-old forest plantations on strip-mined lands in a prairie-forest transition zone of Kansas. Of 13 species tested, sycamore, eastern redcedar, burr oak, loblolly pine, and shortleaf pines performed best. Some analytical data on spoils.

**U.S.-KS : coal-B : VI-B**

216. Geyer, W. A., and G. G. Naughton.
1970. **Growth and management of black walnut (*Juglans nigra* L.) on strip-mined**

**lands in southeastern Kansas.** Kans. Acad. Sci. Trans. 73 (4): 491-501, illus.

Black walnut plantations on strip-mined lands have been established from seed. After 32 years the trees are 6.1 inches dbh and 33 feet high; site index is 40 to 45 feet. Low thinning and single-tree release more than tripled dbh growth compared to unreleased trees. Single-tree release response was best at 0.18 inch. Management of poor-site walnut trees should include early selection of high-quality trees for release and pruning.

**U.S.-KS : coal-B : VI-B**

217. Geyer, Wayne A., and Nelson F. Rogers.
1972. **Spoils change and tree growth on coal-mined spoils in Kansas.** J. Soil and Water Conserv. 27 (3): 114-116.

Black locust, burr oak, sycamore, loblolly pine, and shortleaf pine performed best after 22 years. Tree height increased from lower to upper portions of slopes. Spoil leveling reduced tree growth and form. After 20 years, pH and percentage of soil-sized particles had increased, but P had decreased.

**U.S.-KS : coal-B : VII-D**

218. Gifford, Gerald F., Don D. Dwyer, and Brien E. Norton.
1972. **A bibliography of literature pertinent to mining reclamation in arid and semi-arid environments.** Utah State Univ. 23 p. Logan.

This bibliography lists 312 citations, grouped under 27 headings. Reclamation group covers: ash spoils, coal spoil banks, coppermill tailings, gold from mine tailings, Lignite spoil banks, oil-field waste, oil-shale workings, sand and gravel operations, sandy soils, slag heaps, stone and quarry dust, tin-mine workings, uranium tailings, zinc and lead mining waste. Some foreign sources pertaining to the subject are listed.

**U.S. : coal, ore waste : VIII-E**

219. Given, Ivan A.
1962. **The future in open-pit mining and stripping in the United States.** *In* Conservation — a key to world progress. Soil Conserv. Soc. Am. Proc.: 93-97. Des Moines, Iowa.

A forecast of trends in open-cut and strip mining in the United States by 1970. Metal and nonmetal mineral production will rise and the area affected will increase to 6,000 acres. Sand, gravel, and stone output will increase one-third and the area affected will increase on the same scale as metal and nonmetal mining. Coal output will increase 50 percent, increasing the area affected to 30,000 acres per year.

**U.S. : coal, other : VIII**

220. Good, D. M., V. T. Ricca, and K. S. Shumate.
1970. **The relation of refuse pile hydrology to acid production.** Coal Mine Drain. Res. Symp. 3 Proc.: 145-151. Bitum. Coal Res., Inc., Monroeville, Pa.

The hydrology of a coal-breaker refuse and the acid production were studied. It was observed that: (1) the refuse pile is reactive only at the surface; (2) between rains, the pyrite oxidation reaction proceeds at a uniform rate, the acid products accumulating in the outer mantle; (3) when the storm occurs, about 70 percent of acid salts appear in the runoff and the remainder is carried into the interior of the pile, eventually reappearing as seepage; (4) the rate of acid formation in the pile is 185 pounds acidity per acre day as $CaCO_3$.

**U.S.-IL : coal-R : IV**

221. Goodman, Gordon T., Carole E. R. Pitcairn, and Raymond P. Gemmell.
1973. **Ecological factors affecting growth on sites contaminated with heavy metals.** *In* Ecology and Reclamation of Devastated Land vol. 2: 149-173. Gordon and Breach Sci. Publ., New York.

Factors that prevent or retard germination, establishment, or growth of plants on mine-working dumps in the Swansea Valley are: "sand blasting" wind-barking; diurnal temperature extremes; water stress; low pH; metal toxicity; macronutrient deficiency; and vandalism. To counteract these, N-P-K fertilizer and organic matter were added, and

grass was sown. Trees and shrubs were also grown on the less toxic sites. Heavy metal-tolerant genotypes of grasses were planted. Results show that the latter require less soil treatment and are more productive and persistent than nontolerant grass varieties. However, even highly tolerant grass varieties are of little value on very toxic sites without incorporation of an organic amendment.

**Great Britain : ore waste : III+VI-B**

222. Gooley, Walter.
1974. **What happens after the gravel's gone.** N. Logger 22 (7) : 22, 26.

White and red pine planted on graded gravel pits show promise in turning barren land into productive forest.

**U.S.-ME : sand and gravel : VI-B**

223. Gordon, Alan G., and Eville Gorham.
1963. **Ecological aspects of air pollution from an iron-sintering plant at Wawa, Ontario.** Can. J. Bot. 41: 1063-1078, illus.

Vegetation has been damaged severely by $SO_2$ pollution from iron-sintering plants. It is traceable for 20 miles in a northeasterly direction from the plant, being severe within 11 miles and very severe within 5 miles of the plant. Ground flora declines markedly with respect to the number of plants per unit area and the number of plant species present. The most tolerant species to air pollution are *Polygonum cilinode* and *Sambueous pubens.* Waters up to 5 miles northeast of the plant are strongly acid.

**Canada-ON : ore waste : V-A**

224. Gordon, I. M.
1969. **Erosion control at Hollinger Mine tailing site.** Can. Min. J. 90 (6) : 46-50, illus.

Establishing a vegetative cover on mill tailings is discussed. Fertilizer rates, seedings, and grass species are listed. A novel aspect is use of sewage sludge on the area; highly successful. Scrub trees are planted as a windbreak, and conifers will be planted in subsequent years.

**Canada : ore waste : VI-B**

225. Gorham, Eville, and Alan G. Gordon.
1960. **Some effects of smelter pollution northeast of Falconbridge, Ontario.** Can. J. Bot. 38: 307-312.

Strong sulfate accumulation in the surface soil occurred within 1 mile of the chimneys emitting SO, while effects upon the soil-drainage waters are marked to a distance of 2 miles, and still clearly evident 10 miles away. The number of plant species declines within 4 miles of the smelter, but certain species disappear at much greater distances. Most tolerant are *Acer rubrum, Quercus rubra, Sambucus pubens,* and *Polygonum cilinode.*

**Canada-ON : ore waste : V+V-A**

226. Gorham, Eville, and Alan G. Gordon.
1960. **The influence of smelter fumes upon the chemical composition of lake waters near Sudbury, Ontario, and upon the surrounding vegetation.** Can. J. Bot. 38: 477-487.

Analyses for sulfate, Ca, and pH have been made on waters from the lakes in the Sudbury metal smelting district. Sulfur pollution is high within 5 miles of the smelters, exhibiting from 3 to 10 times sulfate concentration normal for this area. Polluted waters are acid, with pH 3.3. Damage to terrestrial vegetation is marked within 5 miles of smelters. Severe damage occurs chiefly within 2 miles of the smelters.

**Canada-ON : ore waste : V-B**

227. Gorham, Eville, and Alan G. Gordon.
1963. **Some effects of smelter pollution upon aquatic vegetation near Sudbury, Ontario.** Can. J. Bot. 41: 371-378.

The numbers of macrophyte species present in ponds and lakes are inversely related to dissolved sulfates. Although pollution leads to strong acidification, numbers of species are low even where $H_2SO_4$ is almost wholly neutralized. It is suggested that increases in concentration of heavy metals reach the toxic levels near the smelters.

**Canada-ON : ore waste : V-B**

228. Grandt, Alten F.
1948. **The potentialities of revegetating and utilizing agronomic species on strip mined areas in Illinois.** Univ. Ill. Agric. Exp. Stn. and Ill. Coal Strippers Assoc. 1st Yr. Prog. Rep. 32 p., illus.

This report deals principally with the proposed scope and plan of attack on the problem, a statewide survey of spoils, and preliminary reports on a number of seeding projects.

**U.S.-IL : coal-B : I-B+VII-C**

229. Grandt, Alten F.
1949. **The potentialities of revegetating and utilizing agronomic species on strip mined areas in Illinois.** Univ. Ill. Agric. Exp. Stn. and Ill. Coal Strippers Assoc. 2nd Yr. Prog. Rep. 56 p., illus.

This progress report presents further information on spoils, comparing spoil materials with surface soils on adjoining unmined land. Preliminary results are presented on studies of comparative gains made by animals pastured on spoil banks with those pastured on undisturbed blue grass and highly improved grass-legume pasture. The adaptation of various forage species to spoil is discussed.

**U.S.-IL : coal-B : VII-C**

230. Grandt, Alten F.
1950. **The potentialities of revegetating and utilizing agronomic species on strip mined areas in Illinois.** Univ. Ill. Agric. Exp. Stn. and Ill. Coal Strippers Assoc. 3rd Yr. Prog. Rep. 39 p., illus.

Additional information for comparing spoils with soils. Adaptation of forage species to spoils is discussed along with the chemical composition of forage species. Animal weight gains are discussed.

**U.S.-IL : coal-B : VII-C**

231. Grandt, Alten F.
1951. **The potentialities of revegetating and utilizing agronomic species on strip mined areas in Illinois.** Univ. Ill. Agric. Exp. Stn. and Ill. Coal Strippers Assoc. 4th Yr. Prog. Rep. 70 p., illus.

A review of previous annual reports, updating information about forage-crop species adaptation to spoils, spoil chemistry, and weight gains of grazing animals.

**U.S.-IL : coal-B : III-B+VII-C**

232. Grandt, Alten F.
1952. **The potentialities of revegetating and utilizing agronomic species on strip mined areas in Illinois.** Univ. Ill. Agric. Exp. Stn. and Ill. Coal Strippers Assoc. 5th Yr. Prog. Rep. 56 p., illus.

This report summarizes chemical and physical characteristics of strip-mine spoils. Species-adaptation trials are further summarized as are forage yields and animal weight gains. Some effects of liming are presented. Different spoil-grading methods were shown to influence water infiltration.

**U.S.-IL : coal-B : III+VI-A+VII-C**

233. Grandt, Alten F.
1965. **Reclamation for pasture and agricultural crops.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 124-128. University Park.

Mined lands in Illinois are readily adapted to pasture and hay land uses. Other crops can be grown successfully. Spoils can be classified on the basis of acidity and texture. With the exception of N, the plant nutrients are high. Reclaimed spoils are used as pasture for beef cattle. Certain steers gained 2 pounds per day in a 180-day grazing period. Carrying capacity is about 2 acres per animal.

**U.S.-IL : coal-B : VII-C**

234. Grandt, Alten F.
1967. **Agriculture crops.** Ky. Dep. Nat. Resour. Strip Mining Symp. 5 p. Frankfort.

Crops adapted to spoil materials are the forage species — legumes and grasses. Grain crops are rarely used. The kind of crop to be used depends on spoil characteristics.

**U.S.-KY : coal-B : VII-C**

235. Greczta, Jan.
1973. **The recultivation of post-industrial territories.** *In* Protection of Man's Natural Environment. Pol. Acad. Sci. 417 p. Warsaw.

The author analyzes the problems of managing post-industrial wastelands in Poland, discussing trends in the liquidation of post-industrial wastelands; classification of wastelands; the recultivation of wastelands; and legislation and the organization of work in the field of recultivation. Reclamation of coal-mine spoils is emphasized.

**Poland : coal : III+VI**

236. Greszta, Jan, and Stanislaw Morawski.
1972. **Rekultywacja nieuzytkow poprzemyowych (Reclamation of post-industrial waste lands).** State Publ. Co. for Agric. and For. 263 p. Warsaw.

The authors discuss the reclamation efforts of coal-mine spoils for agriculture, forestry, and recreation purposes in Silesian industrial areas of Poland. Physical and chemical characteristics of spoil materials, natural plant succession, physical stabilization of spoils, planting, and planting materials suitable for recultivation are discussed.

**Poland : coal : III+VI**

237. Grim, Elmore C.
1967. **Kentucky's reclamation program.** Ky. Eng. 30(1): 9. Univ. Ky. Coll. Eng., Lexington.

The strip-mining methods employed to recover coal in Kentucky are described, and the implementation of mining and reclamation laws is discussed.

**U.S.-KY : coal-B : II-B+VI**

238. Grim, Elmore C.
1967. **Kentucky after one year.** Ky. Dep. Nat. Resour. Strip Mining Symp. 6 p. Frankfort.

The key provisions of the strip-mining law, passed in 1966, and administration of the law and working relationships with the industry and governmental agencies are discussed.

**U.S.-KY : coal-B : VIII-A**

239. Gronow, Clive W.
1971. **Reclamation problems and needs of the surface mining industry.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 116-126. Ga. Surface Mined Land Use Board. Macon.

A big problem of the industry is the conservationist's emotionalism. To combat this, the industry must bridge the communication gap by educating the general public. Technical and practical problems are: (1) nature of the overburden, (2) climate, (3) mining methods and reclamation costs, and (4) the law.

**U.S.-GA : kaolin : VIII**

240. Grube, Walter E., Jr., Richard M. Smith, Rabindar N. Singh, and Andrew A. Sobek.
1973. **Characterization of coal overburden materials and mine soils in advance of surface mining.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 134-152. Bitum. Coal Res., Inc., Monroeville, Pa.

Chemical analyses of sequential samples of the overburden have provided information about acid-producing potential of different zones of the overburden, and simplified laboratory and field test for determination of (1) pyritic S content, using total S after sulfate removal by leaching; (2) peroxide method to estimate potential acidity; (3) use of color evaluation to measure presence of reduced S; and (4) reaction with dilute acid. Soil testing procedures used for Na, K, Ca, Mg were adequate to evaluate availability of these nutrients for plant growth. The usefulness of the sodium bicarbonate extraction technique for measuring available P is substantiated.

**U.S. : coal : III-B**

241. Guernsey, Lee.
1958. **Reclamation of strip-mined lands**

**in Vigo County, Indiana.** Ind. Acad. Sci. Proc. 67: 215-224, illus.

Topping of the ridges to about 8 feet wide is the procedure for grading spoil banks to be planted in trees. Mixed pines and hardwoods will produce high-quality forests on spoil banks. More intensive land uses can be accomplished by more complete grading and sowing of grasses and legumes. The compaction due to grading has been greatly exaggerated. Construction of dams in the last open cut can provide lakes for recreational areas.

**U.S.-IN : coal-B : VI-A, B**

242. Guernsey, Lee.
1960. **The reclamation of strip mined lands in western Kentucky.** J. Geog. 59 (1) : 5-11, illus.

Outlines the provisions of the Strip Mining and Reclamation Act and discusses the advantages of spoil grading and the effects of tree planting and seeding of grasses and legumes. Potentials of reclaimed areas for recreational uses are pointed out.

**U.S.-KY : coal-B : VI**

243. Gwynn, Thomas A.
1965. **Reclaiming strip-mined land in North Dakota by establishing game management areas.** Knife River Coal Mining Co. 46 p., illus.

Report of Knife River Coal Mining Co. on lignite coal-mine spoils in North Dakota and on company's efforts to revegetate them for game food and cover. It is concluded that the spoils will support the growth of trees and shrubs and that the leveling of spoils is not recommended.

**U.S.-ND : coal-L : VI-B**

244. Gwynn, T. A.
1973. **Environmental implications of developing our coal reserves.** *In* Some environmental aspects of strip mining in North Dakota. N.D. Geol. Surv. Educ. Ser. 5: 87-107.

Environmental implications in strip-mining for lignite are discussed. Effective environmental protection requires a joining together of the best that industry, conservation groups, and government agencies have to offer.

**U.S.-ND : coal-L : V**

245. Hall, Dee.
1965. **Strip mine reclamation under the 1964 act (western Kentucky).** Ky. Dep. Nat. Resour. Strip Mine Reclam Symp. Proc.: 9-10. Frankfort.

Comments on strip-mine reclamation under the provisions of 1964 act as compared with 1962 act.

**U.S.-KY : coal-B : VIII-A**

246. Hall, Ernst P.
1965. **The Sheban project.** Acid Mine Drain. Res. Symp. 1 Proc.: 145-160. Bitum. Coal Res., Inc., Monroeville, Pa.

Water impounded in the strip-mine, and drained through the spoil bank, improved in quality and decreased in quantity with time. Consequently the acid and sulfate load on the receiving stream decreased. Data on physical background of the mine, geology, chemistry of impounded water, spoil biology, and limnology of the water discharged from the mine are presented.

**U.S.-OH : coal-B : IV-H**

247. Hall, Harry H.
1940. **The romance and reclamation of the coal lands of southeastern Kansas.** Kans. Acad. Sci. Trans. 43: 57-67.

A brief history of strip-mining for coal in Kansas. Examples of conversion of waste land for profit such as a quail farm, a state park, and orchards are discussed.

**U.S.-KS : coal-B : VII**

248. Hanna, George P., Jr.
1964. **The relation of water to strip-mine operation.** Ohio J. Sci. 64 (2): 120-124.

A discussion of the hydrologic properties affecting the acid mine problem, the techniques used in gathering data, and the application of these techniques to engineering pro-

cedures. Reference is made to the Beaver Creek study, in regard to application of such knowledge in evaluating the effect of hydrological conditions on water quality. Application of known alleviation methods under controlled conditions and the monitoring of the controls to continue evaluation of the various procedures are urged.

**U.S.-OH : coal-B : IV**

249. Hanson, Edward A.
1968. **Stabilizing eroding streambanks in sand drift areas of the Lake States.** USDA For. Serv. Res. Pap. NC-21. 12 p., illus. N. Cent. For. Exp. Stn., St. Paul, Minn.

Banks are stabilized to protect adjacent high-value items such as cabins and campgrounds or to reduce reservoir or lake sedimentation rates. Also, bank stabilization is undertaken as one part of fish-habitat improvement programs. Rock riprap is the best material for bank stabilization in most cases. It does not deteriorate with time, and it blends in well with surroundings. The upper part of the bank will revegetate naturally. However, sloping and seeding will accelerate vegetation.

**U.S. : other : VI-B+VII-B**

250. Hart, George E., and William R. Byrnes.
1959. **Performance of trees planted on coal-stripped lands in the bituminous region of Pennsylvania.** PA. State For. Sch. Res. Pap. 28. 2 p. University Park.

A summary of 10-year performance of 16 tree species planted on bituminous coal-mine spoils.

**U.S.-PA : coal-B : VI-B**

251. Hart, George E., and William R. Byrnes.
1960. **Trees for strip-mined lands.** USDA For. Serv. NE For. Exp. Stn. Pap. 136. 36 p., illus. Upper Darby, Pa.

Ten-year survival and growth data on 16 tree and 4 shrub species planted on coal-stripped lands in the bituminous region of Pennsylvania are reported. Performance of species is rated, and spoil characteristics are discussed.

**U.S.-PA : coal-B : VI-B**

252. Hashimoto, Nobuyoshi, Toshiro Kojima, Makoto Ogawa, and Tadashi Suzuki.
1973. **Effect of alder and acacia on devastated land.** *In* Ecology and Reclamation of Devastated Land vol. 1: 357-367. Gordon and Breach Sci. Publ., New York.

Hinoki (*Chamaecyparis obtusa* Sieb. and Zucc.), an important silvicultural tree in Japan, can grow vigorously on poor sites when planted with alder (*Alnus tinctoria* Sarg. var. *glabra* Call). After alder planting, soil structure developed strongly; the cation exchange capacity apparently increased and the N and C content of the surface horizon also increased. Acacia also changed the soil conditions but not so favorably.

**Japan : other : III-B+VI-B**

253. Havens, Richard, and Karl C. Dean.
1969. **Chemical stabilization of the uranium tailings at Tuba City, Ariz.** U.S. Dep. Inter. Bur. Mines Rep. Invest. 7288. 12 p.

Acid and basic uranium mill tailings were stabilized against wind erosion by use of an elastomeric polymer on the dike areas and a calcium magnesium lignosulfonate on the beach areas. Cost was $335 per acre. Details of application methods and cost breakdown are given.

**U.S.-AZ : ore waste : VI+VIII-B**

254. Haynsworth, Harry J.
1971. **Experience of Soil Conservation Service in revegetating drastically disturbed sites.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 104-108. Ga. Surface Mined Land Use Board. Macon.

With development of the small watershed program of the SCS, special attention was directed toward selection of plants for vegetating problem areas. As a result of this attention, standards and specifications have been developed for many critical sites in the state of Georgia. The standards and speci-

fications include plant species, rate and dates of seeding, mixtures, fertilizers, lime, and mulch requirements.

**U.S.-GA : other : VI-B**

255. Heide, Gunther.
1973. **Pedological investigations in the Rhine brown-coal area.** *In* Ecology and Reclamation of Devastated Land vol. 2: 295-313. Gordon and Breach Sci. Publ., New York.

Manner and size of recultivation of brown coal spoils are determined by the extent and quantities of the overburden. The Pleistocene and Tertiary strata of sand and gravel are reclaimed for forest. For agriculture, the covering of overburden by loess layer is recommended. The chemical and physical characteristics of the new soils as well as a typological development toward "Parabraunerde" is shown. An increase in nutrient content and productivity under various methods of cultivation is discussed.

**Germany : coal : III+VI-B**

256. Heine, Walter N., and William E. Guckert.
1973. **A new method of surface coal mining in steep terrain.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 105-116. Bitum. Coal Res., Inc., Monroeville, Pa.

In the modified "block-cut" method of mining, work is planned so that overburden from the first cut is placed in a swale or gully on the hillside, and as mining progresses, overburden is deposited in previously mined sections. This method of mining is discussed in relation to the surface mining requirements of Pennsylvania, and it is pointed out that the impact of surface mining is minimized because overburden is not pushed downslope from the mined area to become subject to erosion and landslides.

**U.S.-PA : coal-B : II-B**

257. Hertsgaard, T. A., and F. L. Leistritz.
1973. **Environmental impact of strip mining: the economic and social viewpoint.** *In* Some environmental aspects of strip mining in North Dakota. N.D. Geol. Surv. Educ. Ser. 5: 73-85.

The economic and social implications of strip-mining for lignite are discussed.

**U.S.-ND : coal-L : VIII-B**

258. Higgins, Tom.
1973. **The planning and economics of mined-land use for agricultural purposes.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 287-293. Bitum. Coal Res., Inc., Monroeville, Pa.

The experience of Peabody Coal Company shows that strip-mined land can be restored successfully to agricultural use. Problems with toxic soil can be reduced by mining methods, soil treatment, and choice of plants for seeding. After the reclaimed land has been revegetated, its use depends on its relation to other land in the same area. By company policy, the agricultural land is organized into family farm units. Beef cow-calf operations of live-stock share leasing are used as an example of the costs and benefits incurred in one use of strip-mined land. Experiences with dairying and with farming of hay and row crops and cereal grain crops are also discussed.

**U.S. : coal-B : VII-C**

259. Hill, Lawrence W.
1960. **How precipitation affects strip-mine pond water levels in Southeast Ohio.** USDA For. Ser. Cent. States For. Exp. Stn. Columbus, Ohio.

Precipitation was related to resulting pond-level increase on a 16-acre watershed containing a 5-acre pond. Results showed a close correlation between precipitation and runoff of a strip-mined watershed. Pond level increases became greater as spoil bank : pond ratio became larger.

**U.S.-OH : coal-B : IV-H**

260. Hill, Ronald D.
1970. **Elkins mine drainage pollution control demonstration project.** Coal Mine Drain. Res. Symp. 3 Proc.: 284-303. Bitum. Coal Res., Inc., Monroeville, Pa.

A mine-drainage pollution-control demonstration project near Elkins, W. Va., is described. The effects on water quality of air-scaling, reclamation and reforestation, and diverting water from underground mines were studied. The air-scaling was with small exceptions unsuccessful, and the pollution loads have not decreased. The reclamation and revegetation showed some benefits, but the long-term effects have to be determined. Combined watersheds of Roaring Creek and Grassy Run showed over a 1,500-ton decrease in the acidity load.

**U.S.-WV : coal-B+R : V-B**

261. Hill, Ronald D., and John F. Martin.
1972. **Elkins mine drainage pollution control demonstration project — an update.** Coal Mine Drain. Res. Symp. 4 Proc.: 96-104. Bitum. Coal Res., Inc., Monroeville, Pa.

The Elkins Project has produced both encouraging and discouraging results. The reclamation and revegetation of surface mines and refuse piles have resulted in a decrease in the pollution load from that source. Several years will be required before all the residual pollutants are leached from the reclaimed spoil and the water approaches a stable condition.

**U.S.-WV : coal-B+R : V-B**

262. Hodder, Richard L.
1973. **Surface mined land reclamation research in eastern Montana.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 82-91. Bitum. Coal Res., Inc., Monroeville, Pa.

Rainfall in eastern Montana averages 12 inches per year. Several methods are discussed for making the most effective use of this sparse rainfall in land reclamation. Dryland planting innovations include condensation traps, supplemental root transplanting, and tubelings. Surface manipulation or configuration such as deep chiseling, gouging, or dozer basins are necessary to minimize erosion, relieve compaction, and improve the soil moisture reserve necessary to rapidly establish a desirable lasting vegetative cover.

**U.S.-MT : coal-L : VI-B**

263. Hodgson, D. R., R. Holliday, and F. Cope.
1963. **The reclamation of land covered with pulverized fuel ash: The influence of soil depth on crop performance.** J. Agric. Sci. 61:299-308.

From a study on the restoration of land covered with pulverized fuel ash, the effects of increasing depths of soil on agricultural crop production, and at a range of fertilizer levels, are reported. Results indicate the soil depths needed for successful restoration and the extent to which fertilizers can be used to replace soils.

**Great Britain : fuel ash : VI-B**

264. Hodgson, D. R., and W. N. Townsend.
1973. **The amelioration and revegetation of pulverized fuel ash.** *In* Ecology and Reclamation of Devastated Land vol. 2: 247-271. Gordon and Breach Sci. Publ., New York.

Methods of ameliorating adverse conditions of pulverized fuel ash are discussed. Revegetation of pulverized fuel ash is considered in the context of land restoration for agriculture and other uses. A preliminary classification of trees and shrubs according to ash tolerance and tentative results of trials are reported.

**Great Britain : fuel ash : VI-B+VII**

265. Hoffman, Glenn J., R. Bruce Curry, and Glenn O. Schwab.
1964. **Annotated bibliography on slope stability of strip mine spoil banks.** Ohio Agric. Exp. Stn. Res. Cir. 130. 92 p. Wooster.

This bibliography is compiled in alphabetical order by authors. It lists 366 citations on slope stability of strip-mine spoils and other banks on a global scale, including works in English, German, Russian, French, Italian, and other languages. About 40 references are annotated; subject index.

**U.S. : coal : VIII-E**

266. Hoffman, Glenn J., Glenn O. Schwab, and R. Bruce Curry.
1964. **Slope stability of coal strip mine spoil banks.** Ohio Agric. Exp. Stn. Ser. 8. 24 p. Wooster.

Steepness of slope, excessive soil moisture and a reduction in the shearing resistance of the soil due to severe weathering and freeze-thaw cycles appeared to be important facts in the stability of spoil banks. Numerous other factors make it difficulty to make recommendations on predicting spoil stability.

**U.S.-OH : coal-B : VI-A**

267. Hogg, J. L. E.
1971. **Mined-land reclamation in British Columbia.** For. Chron. 47 (6) : 1-40.

The author discusses the mining industry, the adverse effects of mining operations, reclamation, and the reclamation legislation in British Columbia.

**Canada-BC : coal : VI+VIII-A**

268. Holland, Frank R.
1973. **Wildlife benefits from strip-mine reclamation.** *In* Ecology and Reclamation of Devastated Land vol. 1: 377-388. Gordon and Breach Sci. Publ., New York.

Coal strip-mined areas reclaimed with trees, shrubs, and grasses were compared with untreated spoils 3 years after planting. Large increases in plant basal area, plant canopy area, litter, pH, wildlife cover, and food and vertebrate and invertebrate animal populations were found in the planted areas. Ecologic succession of the test plots was estimated to be 10 years advanced over controls.

**U.S.-TN : coal-B : VI-B**

269. Hollister, Graham.
1962. **Future of federal programs in strip mining and restoration.** *In* Conservation—a key to world progress. Soil Conserv. Soc. Am. Proc.: 87-91. Des Moines, Iowa.

The author points out the magnitude of problems associated with strip mining of natural resources and discusses research needed. Collective action of industry and research and governmental agencies is encouraged. Government programs for research and action are under study.

**U.S. : coal, other : VIII**

270. Hollister, Graham.
1962. **Future of federal programs in strip mining and restoration.** Soil Conserv. Soc. Am. Proc. 1962: 87-91.

The magnitude of problems associated with strip-mining of natural resources is pointed out. Problems needing research are discussed. Collective action of industry and research and government agencies is encouraged. Government programs for research and action are under study.

**U.S. : coal, other : VIII**

271. Howard, Herbert A.
1971. **A measurement of the external diseconomies associated with bituminous coal surface mining.** Eastern Kentucky, 1962-67. Univ. N. M. Nat. Resour. J. 11 (1) : 76-101.

External costs and internal expenses in bituminous coal surface-mining were compared. In recent years, the external costs were reduced, but the mining firm's internal expenses rose because of land reclamation. Data are discussed on a per-ton-mined and acreage-disturbed basis.

**U.S.-KY : coal-B : VIII-B**

272. Howland, John W.
1973. **New tools and techniques for reclaiming land.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 42-67. Bitum. Coal Res., Inc., Monroeville, Pa.

The design and test results of a new blade attachment to earth-moving equipment used in reclaiming strip-mined land. Conditions of spoil handling to be met by the new tool are discussed. A small blade is already in use, and a test on a 40-foot blade (40,000 pounds) was carried out successfully on some spoils.

**U.S. : coal : II-A**

273. Hudson, Charles H.
1971. **Experience of the highway department in revegetating slopes on drastically disturbed sites.** Rehabil. of Drastically Disturbed Surf. Mined Lands Symp. Proc.: 100-103. Ga. Surface Mined Land Use Board. Macon.

The State Highway Department of Georgia has not only gone all out in revegetating slopes, borrow pits, and other disturbed areas in the past few years: it has undertaken to protect these areas from erosion during construction by protective cover, such as temporary grasses and mulches, and also by the use of slope drains, check dams, and other methods.

**U.S.-GA : other : IV-E**

274. Hunt, Clifford F., and W. E. Sopper.
1973. **Renovation of treated municipal sewage effluent and digested liquid sludge through irrigation of bituminous coal strip mine spoil.** Pa. State Univ. Sch. For. Res. Briefs 7 (1) : 11-14.

By irrigating spoils with sludge and effluent, the following effects were observed: (1) spoil removed P, K, Ca, Na, and organic N; (2) applied sludge may create nitrate pollution problems while the effluent alone did not; (3) irrigation with sludge and effluent decreases soluble Fe, Al, Mn, and B.

**U.S.-PA : coal-B : III-B+VI-B**

275. Hutnik, R. J.
1971. **Refuse bank reclamation studied for deep mines.** Sci. in Agric. 18 (3) : 12-13, illus.

A review of problems and approaches in revegetation of coal refuse banks.

**U.S. : coal-B+R : VI-B**

276. Hutnik, Russell J., and Grant Davis, Editors.
1973. **Ecology and reclamation of devastated land.** Gordon and Breach Sci. Publ. Inc., New York. Vol. 1, 538 p. and vol. 2, 504 p.

The two volumes are proceedings from an International Symposium on Ecology and Revegetation of Drastically Disturbed Areas, held in 1969 in Pennsylvania. The symposium brought together 101 scientists from 14 different countries to exchange information and viewpoints on their common problems associated with disturbed areas. The proceedings include 66 formal papers and the discussion that followed each. Volume 1 includes physical and chemical properties, hydrology and pollution, biological changes, and effects on plants. Volume 2 includes species evaluation, modification of adverse conditions, and advances in reclamation. The editors are representatives of the two sponsoring organizations, The Pennsylvania State University School of Forest Resources and the U.S. Forest Service, Northeastern Forest Experiment Station.

**U.S. : coal, other : VIII-D**

277. Hyslop, James.
1964. **Some present day reclamation problems; an industrialist's viewpoint.** Ohio J. Sci. 64 (2) : 157-165.

The industry's viewpoint on the problem of reclamation, with an analysis of the engineering and economic factors related to strip-mining in West Germany and Ohio. They are sufficiently different so that valid comparisons are difficult to make. A great deal of German experiences could be applied here.

**U.S.-OH : coal-B : VIII**

278. Illinois Strip Mine Investigation Commission.
1942. **Report of strip mine investigation commission to the 63rd General Assembly of Illinois.** 40 p.

Statistical data relating to the extent of damage done by strip-mining and the taxation aspect of those lands. The aspect and manner of strip-mining regulations, to be adopted, is reported.

**U.S.-IL : coal-B : VIII-B**

279. Immich, Charles.
1972. **Metal recovery from coal ash to defray costs of mined land reclamation.** Univ. Kans. State Geol. Surv. Spec. Dis-

trib. Publ. 65: 28-29. (1972 Mined Land Workshop Proc.)

Analyses showed that elements Ge, Rb, Th, U, V, and Ti are present in coal ash in quantities sufficient to warrant extraction. The feasibility of such a program is discussed.

**U.S.-KS : fuel ash : III-B**

280. Jacoby, Hermann.
1973. **Growth and nutrition of beech trees on sites of different soil texture in the lignite area of the Rhineland.** *In* Ecology and Reclamation of Devastated Land vol. 1: 391-411. Gordon and Breach Sci. Publ., New York.

Large areas of surface-mined land in the Rhineland are being reclaimed for agriculture and forestry. In an investigation into the growth and nutrition of beech on mined lands, root growth and development was found to be strongly influenced by spoil texture. Differences in height growth between plants grown on spoils, undisturbed forest soil, and on toxic spoil were small. Beech appears to be well-suited for planting on alkaline spoil sites.

**Germany : coal-L : VI-B**

281. James, A. L.
1966. **Stabilizing mine dumps with vegetation.** Endeavor 25: 96.

The author describes experiments using vegetation to stabilize the waste materials from gold mines of the Witwatersrand in South Africa and the methods used to alter the chemical natures of the dumps so that the vegetation would form a permanent establishment.

**S. Africa : ore waste : VI-B**

282. Jamison, George M.
1965. **Mined area restoration of tomorrow.** J. Soil and Water Conserv. 20 (4): 186-188.

Principal aspects of restoration of mined areas: revegetation, spoil chemistry, hydrology, and earth movement are viewed in the perspective of future research challenge.

**U.S. : coal : VI**

283. Jewell, Samuel R., and Ronnie J. Haynes.
1973. **A survey of the status of Illinois coal surface-mined lands created prior to January 1, 1962 (pre-law).** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 334-350. Bitum. Coal Res., Inc., Monroeville, Pa.

The Cooperative Wildlife Research Laboratory of Southern Illinois University conducted in 1970 and 1971 a survey of the lands in Illinois affected by surface mining for coal prior to 1 January 1962 to update existing knowledge of the acreage, ownership, condition, and utilization of these lands. The total affected land encompassed 108,447 acres. Most of the affected land is in private coal-company ownership (81,063 acres) and is not utilized, in pasture, or in organized recreation use (85,921 acres). However, only a small percentage of the land constitutes a severe pollutional problem; and the reclamation of this land, although necessary, must be scientifically planned and executed to produce long-term environmental gains.

**U.S.-IL : coal-B : I-B**

284. Johnson, Edward A.
1965. **Research in strip mine reclamation.** Ky. Dep. Nat. Resour. Strip Mine Reclam. Symp. Proc.: 11-18. Frankfort.

Outlines research work conducted at U.S. Forest Service Laboratory in Berea. The project depends upon the cooperation of industry, universities, and other public agencies.

**U.S.-KY : coal-B : VIII-C**

285. Johnson, Edward A.
1965. **Forest restoration of strip-mined land: a research challenge.** Acid Mine Drain. Res. Symp. 1 Proc.: 199-206. Bitum. Coal Res., Inc., Monroeville, Pa.

An outline of the research program conducted by the USDA Forest Service on revegetation methods and techniques for stabilizing spoil banks by establishing vegetation to ascertain the nature of spoil chemical characteristics; to amend those conditions that retard vegetation or pollute water; to determine the hydrologic processes that influence the quality

and quantity of water; and to develop standards for safeguarding, improving, and developing water resources.

**U.S. : coal-B : VIII-C**

286. Jonas,Frantisek.
1973. **Reclamation of areas damaged by mining activity in Czechoslovakia.** *In* Ecology and Reclamation of Devastated Land vol. 2: 379-394. Gordon and Breach Sci. Publ., New York.

Reclamation work on lands devastated by coal-mining is discussed from engineering and biological aspects. The engineering aspect consists of grading and leveling earth heaps, the biological deals with establishing vegetation for agriculture and forest uses. Examples of successful reclamation practices are given. Reclamation is viewed as an integral part of the coal-mining processes.

**Czechoslovakia : coal-L : VI**

287. Jones, W. G.
1959. **Progress report on the reclamation and reforestation of strip-mined areas in central Pennsylvania.** 12 p., illus. Cent. Pa. Open Pit Min. Assoc., Philipsburg.

A pictorial report on successful reclamation accomplishments by coal-mining industries.

**U.S.-PA : coal-B : VII-D**

288. Jones, W. G.
1970. **The new forest.** 58 p., illus. Offset Centre, Inc., Boalsburg, Pa.

This book offers a pictorial story of reclamation successes accomplished on strip-mined lands, to create a new forest with a multiple-use perspective.

**U.S.-PA : coal-B : VII-D**

289. Jones, J. N., Jr., W. H. Arminger, and G. C. Hungate.
1973. **Seed ledges improve stabilization of outer slopes on mine spoil.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 250-258. Bitum. Coal Res., Inc., Monroeville, Pa.

Stabilization of slopes by the establishment of persistent vegetation is demonstrated. Stair-step terraces and grooves constructed with hand tools were evaluated. Plots were limed and seeded or planted with birdsfoot trefoil, alone or with crownvetch. All plots were seeded with weeping lovegrass. Phosphate or superphosphate were used as fertilizers. It was suggested that the extra effort in transplanting the legumes is not necessary when a good stand of seeded weeping lovegrass and K31 fescue can be established. Improved soil-water relations in the grooves, the banding effect of the seed, and fertilizer favored rapid plant establishment and slope stabilization.

**U.S.-WV : coal-B : VI**

290. Jukkola, W. H., H. E. Steinman, and E. F. Young, Jr.
1968. **Coal mine drainage treatment.** Coal Mine Drain. Res. Symp. 2 Proc.: 376-385. Bitum. Coal Res., Inc., Monroeville, Pa.

Because of the geological and chemical factors involved in the formation of mine drainage, no two mines and no two drainage sources are exactly the same. In some cases proper mine engineering has resulted in drainage that causes no pollution. In many others, pollution exists in varying extents. Selection of a treatment scheme where pollution exists is very much a problem of the individual drainage, its volume, characteristics, and location.

**U.S.-PA : coal-B : IV**

291. Jurgens, Leonard.
1972. **Suitable plant materials for various uses on reclaimed mined land in southeast Kansas.** Univ. Kans. State Geol. Surv. Spec. Distrib. Publ. 65: 7-9. (1972 Mined Land Workshop Proc.)

Warm-season grasses can be established on newly smoothed strip-mined lands. A mixed stand is better than pure plantings. K-31 and southern brome require fertilization. Emerald crownvetch is good for erosion control and Cicer milkvetch for good cover.

Cardinal autumn olive and Tartarian or Amur honeysuckle are recommended for beautification and wildlife.

**U.S.-KS : coal-B : VI-B**

292. Kansas State Geological Survey.
1972. **Mined land workshop proceedings.** Univ. Kans. State Geol. Surv. Spec. Distrib. Publ. 65. 29 p.

This workshop report contains nine papers on various aspects of reclamation of strip-mined lands: agriculture, forestry, recreation, hydrological properties, soil compaction, and utilization of fly ash as a soil amendment.

**U.S.-KS : coal-B : VIII-D**

293. Kays, Carl E.
1967. **Strip-mined lands as fish and wildlife habitat.** Ky. Dep. Nat. Resour. Strip Mining Symp. 5 p. Frankfort.

Most of the evicted wildlife returns to strip-mined areas. The rate of reoccupation is related to the establishment of attractive food and cover. A list of native and exotic game food and cover plants readily invading the strip-mine spoils is given, and a list of the game species that use strip-mine habitat. Strip-mine lakes as fish habitat are discussed.

**U.S.-KY : coal-B : VII-E**

294. Kentucky Department of Natural Resources.
1965. **Strip-mining in Kentucky.** Ky. Dep. Nat. Resour. 56 p., illus.

An overview of strip-mining in Kentucky, including historical, geological, economic, legislative, and regulatory reclamation research and applied reclamation aspects of the strip-mining industry.

**U.S.-KY : coal-B : VIII**

295. Kentucky Department of Natural Resources.
1965. **Proceedings of the symposium on strip-mine reclamation.** Ky. Dep. Nat. Resour. 47 p., illus.

Contains 12 papers by mining company officials, researchers, and federal and state government officials on the status of coal surface mining and reclamation in Kentucky.

**U.S.-KY : coal-B : VIII-D**

296. Kentucky Department of Natural Resources.
1967. **Strip Mining Symp.** Ky. Dep. Nat. Resour. Div. Reclam. 104 p., illus. Frankfort.

This proceeding report contains 18 reports on a survey of state and federal agencies, industry, conservationists, and landowners for programs, policies, and operating techniques for achieving wise use and development of Kentucky's natural resources.

**U.S.-KY : coal-B : VIII-D**

297. Kentucky Division of Reclamation.
1972. **Surface mining and reclamation in Kentucky.** Ky. Div. Reclam. 48 p., illus.

An overview of the problems and progress in surface mining and reclamation in Kentucky, with emphasis on the mining of coal. Hypothetical examples are given of the legal, administrative, and technological aspects of surface mining and reclamation on both the eastern and western Kentucky coal fields.

**U.S.-KY : coal-B : VI**

298. Kentucky Legislative Research Commission.
1949. **Strip-mining in Kentucky.** Ky. Legis. Res. Comm. Publ. 5. 54 p., illus.

A report and recommendations on strip-mining in Kentucky with a view to enactment of legislation in compliances with Senate Resolution 74 of the 1948 General Assembly.

**U.S.-KY : coal-B : VIII-A**

299. Kentucky Legislative Research Commission Research Staff.
1954. **Strip mining: a 1954 legislative problem.** Ky. Legis. Res. Comm. Inf. Bull. 10. 15 p.

Relates problems and recommendations for regulating surface mining in Kentucky.

**U.S.-KY : coal-B : VIII-A**

300. Kieffer, F. V.
1972. **A bibliography of surface coal mining in the United States.** 71 p. Forum Associates, Columbus, Ohio.

This bibliography lists about 730 citations dealing with surface coal mining and the ecology of disturbed lands. The citations are subdivided into 10 sections: bibliography; books; academic publications, symposium proceedings and other works; federal government publications and studies known to be contracted by federal government agencies; master's theses and doctoral dissertations; newspaper articles; popular magazines; professional and scholarly journals; state government publications; trade journals and industry publications.

**U.S. : coal : VIII-E**

301. King, Robert.
1967. **Forestry.** Ky. Dep. Nat. Resour. Strip Mining Symp. 3 p. Frankfort.

The experiences, views, and concerns of a practicing forester involved in growing, culturing, and harvesting the forest on strip-mined lands.

**U.S.-KY : coal-B : VII-D**

302. Kinney, Edward C.
1964. **Extent of acid mine pollution in the United States affecting fish and wildlife.** U.S. Dep. Inter. Bur. Sport Fish. and Wildl. Circ. 191. 27 p., illus.

Data on the waters in the United States having potential for fish and wildlife which are deleteriously affected by acid mine pollution. It was found that 5,890 miles of streams and 14,967 acres of impoundments have a potential for fish and wildlife habitat if the acid pollution were sufficiently reduced.

**U.S. : Coal : IV-G**

303. Knabe, Wilhelm.
1962. **The reclamation of lands stripped for brown-coal.** Ohio Agric. Exp. Stn. For. Dep. Ser. 49.

A summary of Knabe's work translated from German by P. Koller. A discussion of the problem of strip-mining, its consequences and reclamation in East Germany, and an outline of the soil-testing methods used in reclamation of spoils.

**Germany : coal-L : VI**

304. Knabe, Wilhelm.
1964. **Methods and results of strip-mine reclamation in Germany.** Ohio J. Sci. 64: 75-105

A report on trends in mining and land reclamation in Germany. Topics discussed are: coal-mining areas; reclamation as an integral part of strip-mining; the agricultural value of the overburden; mining equipment and its effect on reclamation; agricultural reclamation; afforestation; and amelioration of spoil banks.

**Germany : coal-B : II+VI+VII**

305. Knabe, Wilhelm.
1964. **A visiting scientist's observations and recommendations concerning strip-mine reclamation in Ohio.** Ohio J. Sci. 64: 132-157.

Observations and recommendations on reclamation of strip-mined lands in the United States: mining and reclamation have to be an inseparable unity; reclamation has to be preplanned; because it is an economic matter, costs and results of reclamation have to be in proper balance; we cannot continue the bad practice of wasting the land; voluntary cooperation of the mining companies, and training the people of industry, farmers, and foresters in various aspects of reclamation and land management is suggested.

**U.S.-OH : coal-B : VI**

306. Knabe, W.
1965. **Observations on world-wide efforts to reclaim industrial waste-land.** *In* Ecology and the industrial society. Brit. Ecol. Soc. Symp. 5. 296 p. Blackwell Sci. Publ., Oxford.

Observations on reclamation work in the United States and European countries. Studies indicate that the absence of vegetation and coal-mine spoils is due to either fresh disturbance or the detrimental effects of site

factors such as toxic ingredients or the unstable nature of the spoils. The aims of reclamation are to return waste lands to economic or recreational use. Three approaches have been observed: (1) accepting the site conditions as they are and planting the area with pioneer plants of low site requirements. (2) Changing bad sites by reshaping the contours and by adding soil amendments before or after planting. (3) Planning future land use before displacing the waste and following this by restoring fertility to the site, which may become productive once again.

**U.S. : other, coal : VI**

307. Knabe, Wilhelm.
1973. **Development and application of the "Domsdorf ameliorative treatment" on toxic spoil banks of lignite opencast mines in Germany.** *In* Ecology and Reclamation of Devastated Land vol. 2: 273-293. Gordon and Breach Sci. Publ., New York.

Primary factors preventing plant growth on the lignite spoils in Eastern Germany are acidity, deficiency in main nutrients, excess of minor elements, and the water-repellant nature of the material. Ways of soil amelioration were found so that trees and other crops showed good growth. The treatments consisted of application of calcareous and hydroscopic ash from lignite-burning power plants, fertilization, and deep soil cultivation. Later improvements involve a more precise assessment of lime requirements and selection of the most calcareous ashes.

**Germany : coal-L : III**

308. Knabe, Wilhelm.
1973. **Investigations of soils and tree growth on five deep-mine refuse piles in the hard-coal region of the Ruhr.** *In* Ecology and Reclamation of Devastated Land vol. 1: 307-324. Gordon and Breach Sci. Publ., New York.

Slag heaps from deep coal mines, burned and unburned, have been investigated as to soil development and revegetation. Soils described as "Halden-Rohboden" and "Halden-Ranker" are characterized by high macroporosity (even deep underground), thermal activity, and weathering of pyrites. They are also affected by dustfall and acid precipitation in the Ruhr. Revegetated sites showed improved nutrient status and pH in the top layer. Some relationships between soil and tree growth are discussed. Suggestions for future plantings are given.

**Germany : coal-R : III+VI**

309. Knudsen, Lyle L.
1953. **A pine planting on old strip-mine banks.** Ohio Agric. Exp. Stn. For. Mimeo 5. 2 p.

Tests on a 17-year-old plantation of red and Scotch pines on Muskingum County spoils showed that under certain conditions pines can be grown successfully.

**U.S.-OH : coal-B : VII-D**

310. Knudsen, Lyle L., and Paul H. Struthers.
1953. **Stripmine reclamation research in Ohio.** Ohio J. Sci. 53: 351-355, illus.

A summary of early attempts to solve reclamation problems in Ohio. Research programs of the Ohio Agricultural Experiment Station and of the U.S. Forest Service Central States Forest Experiment Station, and the cooperative action of the Ohio Reclamation Association, are discussed.

**U.S.-OH : coal-B : VIII-C**

311. Knutson, Robert.
1970. **A look at the mine-timber market in the Appalachian Bituminous Coal Region.** USDA For. Serv. Res. Pap. NE-147. 9 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

About 1 board foot of sawed timbers and 0.54 lineal foot of round and split timbers are now used for every ton of bituminous coal produced from underground coal mines in the Appalachian coal region. Favored species for mine timbers are the dense hardwoods such as oak, hickory, and beech. The tonnage of coal produced from underground mines is expected to increase in future years, so volume of wood used in coal mines is also expected

to increase. Sawmill operators are advised to consider this market as a potential outlet for their products.

**U.S. : coal-B : II**

312. Kochanowsky, Boris J.
1965. **The coal stripping operation.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 72-76. University Park.
An analysis of the coal-stripping operation is given. Topics discussed: drilling and blasting, shovel and dragline, coal-haulage, coal stripping at greater depths, and land restoration.

**U.S.-PA : coal-B : II**

313. Kohnke, Helmut.
1941. **The black alder as a pioneer tree on sand dunes and eroded land.** J. For. 39: 333-334.
The alders deserve attention in trials with other control measures for stabilizing disturbed lands.

**U.S. : coal-B : VI-B**

314. Kovacic, William J.
1972. **The use of fly ash on the acid soil of reclaimed mined land.** Univ. Kans. State Geol. Surv. Spec. Distrib. Publ. 65: 26-27. (1972 Mined Land Workshop Proc.)
Fly ash will improve acid strip-mined lands. Estimated cost of and revenue from reclamation are discussed.

**U.S.-KS : coal-B : VI-B**

315. Krause, Rodney R.
1964. **Spoil bank goes from waste to fodder.** Coal Min. and Process. 1 (5): 29-31.
A 10-year research program on successful reclamation of strip-mined lands for pasture. Data on macro- and micro-nutrient status.

**U.S.-OH : coal-B : VII-C**

316. Krause, Rodney R.
1965. **Equipment and extractive advances spoil stratification.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 77-81. University Park.
Spoil stratification improves the capacity of an area to produce vegetation. Advances in mining equipment have been accompanied by problems in both mining and reclamation work. Operating characteristics of the advanced stripping equipment are outlined.

**U.S. : coal-B : II**

317. Krause, Rodney R.
1967. **Innovations in reclamation work.** Ky. Dep. Nat. Resour. Strip Mining Symp. 9 p. Frankfort.
A review of the knowledge, ideas, techniques, tools, and machinery applicable in reclamation work.

**U.S. : coal-B : II**

318. Krause, Rodney R.
1971. **Methods and techniques in mined land reclamation.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 15-21. Ga. Surface Mined Land Use Board. Macon.
Methods of overburden placement, sheet-erosion control, and seeding are discussed. Technological advances in pH testing, mechanized tree planters, and planting guns are described as are advances in knowledge of tree and grass species that can live under severe chemical, physical, and climatic conditions.

**U.S. : coal-B : II+VI**

319. Krause, Rodney R.
1972. **Recovery of mined land.** Coal Min. and Process. 9 (1): 51-56.
A survey of the latest technique in mining, control of rainfall, acidity determination, planting tools, and desirable types of vegetation that will maximize proper reclamation of land surfaces disturbed by strip-mining.

**U.S. : coal-B : VI**

320. Krause, Rodney R.
1972. **Mining and reclamation techniques to control mine drainage.** Coal Mine

Drain. Res. Symp. 4 Proc.: 425-430. Bitum. Coal Res., Inc., Monroeville, Pa.

Remarks on surface mining and grading methods — conventional and imaginative — in mountainous terrain of Appalachia. The combined activities of earth-moving practices and reclamation to control erosion and water pollution are stressed.

**U.S. : coal-B : II-B**

321. Krause, Rodney R.
1973. **Predicting mined-land soil.** *In* Ecology and Reclamation of Devastated Land vol. 1: 121-131. Gordon and Breach Sci. Publ., New York.

The key to achieving predictable growing medium lies in identifying which combination of overburden strata is best suited for the survival and growth of vegetation. The approach involves the analysis of weathered in-place overburden materials and their handling in the mining and grading process.

**U.S.-OH : coal-B : VI-A**

322. Laing, R. T.
1950. **Open-pit mining.** Pa. For. and Waters 2 (5): 100-101, 113-114, illus.

Here is how the industry views the development of open-pit mining for coal in Pennsylvania and problems associated with reclamation. "By wise planning-experimentation-research and sincere unselfish devotion to the welfare of our State, this end can and will be accomplished."

**U.S.-PA : coal-B : VIII**

323. Lamm, Arnold E.
1967. **Role of coal industry in planning and implementing development of a state or regional program.** Ky. Dep. Nat. Resour. Strip Mining Symp. 7 p. Frankfort.

A general discussion of the complex problems, challenges, and responsibilities that confront the coal-mining industry.

**U.S.-KY : coal-B : VIII-B**

324. Lane, Richard D.
1967. **Cooperative strip mine research.** Ky. Dep. Nat. Resour. Strip Mining Symp. 2 p. Frankfort.

A summary of past and present U.S. Forest Service research programs on restoration of strip-mined lands.

**U.S. : coal-B : VIII-C**

325. Lane, Richard D.
1968. **Forest service reclamation research.** Min. Congr. J. 54 (5): 38-42.

The role of the Forest Service in surface-mine reclamation research is discussed along with a history of research and its prime objectives. The research program is concentrated in four major areas: hydrology, engineering, soil science, and revegetation. Study results are reported so as to be applied to reclamation programs.

**U.S. : coal : VIII-C**

326. Lejcher, Terrence R.
1972. **Strip mine reclamation utilizing treated municipal wastes.** Proc. Res. Assoc. and Colo. State Univ. Am. Water Nat. Symp. Watersheds in Transition Proc.: 371-376.

The application of anaerobically digested sewage sludge has improved water quality and spoil pH and has allowed establishment of vegetative cover. Both vegetative cover and water-quality responses were directly related to the rate of sludge application.

**U.S.-IL : coal-B : VI-B**

327. Lejcher, Terrence R., and Samuel H. Kunkle.
1973. **Restoration of acid spoil banks with treated sewage sludge.** *In* Recycling treated municipal wastewater and sludge through forest and cropland: 184-199. Pa. State Univ. Press, University Park and London.

Preliminary results of the strip-mine-reclamation project in Illinois. Treated municipal sludge, when applied to the spoil in sufficient amounts, improves pH, allows establishment of vegetation, and reduces acidity and concentrations of some of the chemicals. The proposed application of sludge should provide

some insight into the practicality of sludge treatment on strip-mined areas.

**U.S.-IL : coal-B : VI**

328. Limstrom, G. A.
1948. **Extent, character, and forestation possibilities of land stripped for coal in the Central States.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 109. 79 p., illus. Columbus, Ohio.

Results of reconnaissance in 1946 and 1947 of lands stripped for coal in the Central States. Basic site factors, acidity, texture, topography, and stability, as they affect reforestation practices, are discussed. A tentative guide recommends tree species for planting on the principal spoil types of different textures and in the various acidity classes. Problems that need further research are listed. Appendix contains statistics by state and counties showing extent of acidity and textural classes, coal seams, and character of vegetation.

**U.S. : coal-B : III+VII-D**

329. Limstrom, G. A.
1950. **Overburden analyses and strip-mine conditions in mideastern Ohio.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 117. 33 p. Columbus, Ohio.

A summary of the reconnaissance data for spoil-bank conditions in strip-mining District No. IV in Ohio. Tabulations show physical characteristics of individual strata along with acidity levels and P and K availability.

**U.S.-OH : coal-B : III**

330. Limstrom, G. A.
1950. **Overburden analyses and strip-mine conditions in northeastern Ohio.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 114. 44 p.

A summary of the reconnaissance data for spoil-bank conditions in strip-mining Districts No. I and II in Ohio. Tabulations show physical characteristics of individual strata along with acidity levels and P and K availability.

**U.S.-OH : coal-B : III**

331. Limstrom, G. A.
1952. **Effects of grading strip-mined lands on the early survival and growth of planted trees.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 130. 35 p., illus. Columbus, Ohio.

Results on survival and height growth of forest plantations and moisture conditions on graded and ungraded strip-mined lands in Ohio, Illinois, and Kansas, showing a harmful effect of grading on the early development of planted trees. The effects vary with the texture of spoil and climate conditions. On coarse-texture spoils in areas of uniform rain frequency, the differences in tree growth are negligible and on fine-texture spoils with extreme rainfall, variations in survival and growth were significantly better on the ungraded banks.

**U.S.-OH, IL, KS : coal-B : III-C+VI-B**

332. Limstrom, G. A.
1953. **A bibliography of strip-mine reclamation.** USDA For. Serv. Cent. States For. Exp. Stn. Misc. Rel. 8. 25 p. Columbus, Ohio.

A list of 135 papers published from 1918 to 1953 containing information about reclamation of coal-mine spoils, plus 113 additional references that may be useful in the study of specific phases of strip-mine reclamation.

**U.S. : coal : VI+VIII-E**

333. Limstrom, G. A.
1960. **Forestation of strip-mined land in the Central States.** USDA Handb. 166. 74 p., illus.

A summary of knowledge gained during the decades 1940-1960 and a guide for those engaged in forestation of strip-mined lands in Central States. Site characteristics and planting operations are discussed in considerable detail.

**U.S. : coal-B : III+IV-E+VI-B+VII-D**

334. Limstrom, G. A.
1964. **Revegetation of Ohio's strip-mined land.** Ohio J. Sci. 64 (2) : 112-119.

The success of strip-mine revegetation is in-

fluenced by the spoil parent material, the way the material is manipulated in mining and grading, site characteristics, and planting technique. Spoil texture, aggregation, topography, acidity, and grading have to be appraised prior to planting. The choice of species, planting methods, and planting-stock quality have to be considered.

**U.S.-OH : coal-B : III+VI-B**

335. Limstrom, G. A., and G. H. Deitschman.
1951. **Reclaiming Illinois strip coal lands by forest planting.** Univ. Ill. Agric. Exp. Stn. Bull. 547: 201-250, illus.

A survey report of existing plantations on lands strip-mined for coal. Performance was related to main site characteristics. Tree survival averaged about 60 percent. Eight conifers and ten hardwoods were tentatively recommended for plantings. Sweetgum was the most promising species. Black locust is a good indicator for site quality and a valuable nurse crop for black walnut, silver maple, and yellow-poplar, but not for cottonwood, sweetgum, or osage orange. Important site characteristics are discussed.

**U.S.-IL : coal-B : VI-B**

336. Limstrom, G. A., and R. W. Merz.
1949. **Rehabilitation of lands stripped for coal in Ohio.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 113. 41 p., illus.

The authors describe the varied and complex site conditions on strip-mine lands. Possible uses of these lands are suggested, and recommendations are made for forest planting.

**U.S.-OH : coal-B : VI-B**

337. Limstrom, G. A., and R. W. Merz.
1951. **Overburden analyses and strip-mine conditions in southeastern Ohio.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 127. 61 p., illus. Columbus, Ohio.

Summary of 1945-47 reconnaissance survey of lands stripped for coal in southeastern Ohio, including information about local geological conditions.

**U.S.-OH : coal-B : I**

338. Limstrom, G. A., and R. W. Merz.
1951. **Overburden analyses and strip-mine conditions in the northwestern district of the Ohio coal mining region.** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 124. 36 p., illus.

A summary of reconnaissance data for spoil-bank conditions in strip-mining District No. III in Ohio. Tabulations show physical characteristics of individual strata along with acidity levels and P and K availability.

**U.S.-OH : coal-B : III**

339. Lorenz, Walter C.
1962. **Progress in controlling acid mine water: a literature review.** U.S. Bur. Mines Inf. Circ. 8080. 40 p.

A review of literature relating to the problems of acid mine drainage from bituminous coal mines. It is evident that the coal industry has been offered many practical tools for diminishing pollution. The industry has applied many of the control measures, yet there are still many areas of conflicting thought. More information is needed for identifying and disposing of acid-forming material.

**U.S. : coal : IV**

340. Lorenz, Walter C., and Robert W. Stephan.
1967. **Factors that affect the formation of coal mine drainage pollution in Appalachia.** U.S. Bur. Mines. 17 p. Pittsburgh, Pa.

A literature review on the extent of the mine-drainage problem in Appalachia. It was found that pyrite is formed contemporaneously with the formation of coal, is associated with coal and rocks adjacent to the coal, and its oxidation produces stream pollutants. Current research on pyrite oxidation includes electrochemical reactions and the effects of iron-oxidizing bacteria on oxidation.

**U.S. : coal : V-B**

341. Lorenz, Walter C., and Robert W. Stephan.
1967. **The oxidation of pyrite associated with coal mines.** U.S. Bur. Mines. 21 p. Pittsburgh, Pa.

A survey of literature and current research on both the chemical and bacterial oxidation of pyrite. Factors affecting the rates of pyrite oxidation are oxygen concentration, particle size, temperature, moisture, pH, electrode potential of the reaction, and a possible catalyst. Iron- and sulfur-oxidizing bacteria increase the rate of oxidation. A number of methods are being developed to circumvent, inhibit, counteract, or abate the pollution of mine water. None of these have proved to be satisfactory. Research on electrochemical properties and the effects of bacteria and surface treatment of pyrite is promising.

**U.S. : coal : V-B**

342. Lorenz, Walter C., and Edward C. Tarpley.
1963. **Oxidation of coal mine pyrites.** U.S. Bur. Mines Rep. Invest. 6247. 13 p.

Samples of materials containing pyrite, taken from coal mines and coal beds, were studied for composition and oxidizing characteristics. The pyrites occurred in spherical clusters of small crystals. An iron-oxidizing bacterium acted as a catalyst, greatly increasing the oxidation rates. No definite correlation of results with the location of mines nor with the acidity or alkalinity of mine drainage was found.

**U.S. : coal : V-B**

343. Lorio, P. L., Jr., and G. E. Gatherum.
1965. **Relationship of tree survival and yield to coal-spoil characteristics.** Iowa State Univ. Sci. and Tech. Res. Bull. 535: 394-403, illus.

Performance of two hardwoods and five conifers was related to the chemical characteristics of coal-spoil material. Regression analyses revealed that tree survival was related to pH, soluble salts exchangeable Al, cation exchange capacity, and N; the yield of cottonwood was related to exchangeable Al and soluble salts; eastern red cedar to slope position, N and soluble salts; pitch pine to cation exchange capacity and exchangeable and soluble bases.

**U.S.-IA : coal-B : III-B+VI-B**

344. Lorio, P. L., Jr., and G. E. Gatherum.
1966. **Growth of eastern cottonwood in relation to coal-spoil characteristics.** Iowa State J. Sci. 41 (1) : 41-53.

Growth of eastern cottonwood was related to the chemical characteristics of spoil material. The variables best related to total tree height were salt concentration, exchangeable and soluble Ca, and percentage of soil-size material. Foilage and spoil analyses and leader growth indicated N and P deficiencies.

**U.S.-IA : coal-B : III-B+VI-B**

345. Lorio, P. L., Jr., G. E. Gatherum, and W. D. Shrader.
1964. **Tree survival and growth on Iowa coal-spoil materials.** Iowa Agr. and Home Econ. Exp. Stn. Spec. Rep. 39. 12 p., illus. Ames.

Early results show that green ash survived better and cottonwood grew much faster than other species on a variety of spoils. On calcareous spoils, performance of red cedar was best, but pines grew and survived poorly. Pines preferred acid spoils.

**U.S.-IA : coal-B : VI-B**

346. Lowry, Gerald L.
1956. **Five-year study evaluates forest trees varieties for spoil banks.** Ohio Agric. Exp. Stn. Ohio Farm and Home Res. 41: 70-71., illus. Wooster.

Early performance of certain forest species planted on spoils is discussed.

**U.S.-OH : coal-B : VI-B**

347. Lowry, Gerald L.
1958. **Conifer growth and survival varies on acid spoils.** Ohio Agric. Exp. Stn. Ohio Farm and Home Res. 43 (311). 2 p. Wooster.

Seedling survival and height growth for 2-year-old conifer plantations are discussed. Spoil is described.

**U.S.-OH : coal-B : VI-B**

348. Lowry, Gerald L.
1960. **Conifer growth is best on acid spoils.** Ohio Agric. Exp. Stn. Ohio Farm and Home Res. 45 (3) : 45. Wooster.

Growth of conifers is less than that of hardwoods. Spoils susceptible to erosion should be planted to hardwoods.

**U.S.-OH : coal-B : VI-B**

349. Lowry, Gerald L.
1960. **Conifer establishment on coal spoils as influenced by certain site factors and organic additions at planting time.** Soil Sci. Soc. Am. Proc. 24 (4) : 316-318.

Eight conifer species were planted on spoils of different site characteristics. Root-mulch treatments were tried. After 2 years, significant differences in survival were noted between tree species and also due to mulching on very strongly acid sandy spoils. No differences in height growth were noted. A prediction equation for survival, based on site characteristics, is given.

**U.S.-OH : coal-B : VI-B**

350. Lowry, Gerald L.
1961. **Alder appears promising as spoil bank tree planting.** Ohio Agric. Exp. Stn. Ohio Farm and Home Res. 46 (4) : 12, illus. Wooster.

European and speckled alders performed well when planted with other hardwoods on spoils of a wide textural range and of pH 3.5 and above.

**U.S.-OH : coal-B : VI-B**

351. Lowry, G. L., F. C. Brokaw, and C. H. Breeding.
1962. **Alder for reforesting coal spoils in Ohio.** Ohio J. For. 60 : 196-199, illus.

Black and speckled alder survived and grew well on a wide range of Ohio spoils and other site conditions. Their ability to stabilize steep slopes is not as good as that of black locust. The prime deterrents to good performance of alders are excessive competition and extreme spoil acidity. Economic returns from alders are anticipated to be greater than those from black locust; thus the alders could replace black locust in future spoil-bank plantings.

**U.S.-OH : coal-B : VI-B**

352. Lowry, Gerald L., and James H. Finney.
1962. **A lysimeter for studying the physical and chemical changes in weathering coal spoil.** Ohio Agric. Exp. Stn. Res. Circ. 113. 17 p., illus.

Describes a lysimeter installation for studying the changes in physical, chemical, and biological properties of weathering coal spoils. Construction, instrumentation, and operation of the installation are treated in detail.

**U.S.-OH : coal-B : III**

353. Ludwig, Walter D.
1923. **Reforestation by coal companies in southwestern Pennsylvania.** J. For. 21 : 492-496.

Industrial timber demands, reforestation needs, accomplishments, and obstacles encountered in tree-planting programs in southwestern Pennsylvania are discussed.

**U.S.-PA : coal-B : VII-D**

354. McCarthy, Richard E.
1973. **Preventing the sedimentation of streams in a Pacific Northwest coal surface mine.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 277-286. Bitum. Coal Res., Inc., Monroeville, Pa.

Because soil particles were claylike and tended to remain in suspension, polyelectrolyte flocculant treatment was used in addition to settling ponds. The method of treating the water and the laboratory and field work carried out in developing the treatment process are described. The process is designed to handle the extended periods of high runoff and occasional peak flows common to the area. It has also been automated to continually monitor the water flow and to add

the correct amount of flocculant into the turbid water. Water analysis three times a day above and below the mine assures that the overflow from the final settling pond does not carry siltation that would destroy the migratory fish population.

**U.S.-WA : coal : IV**

355. McClain, Thomas J.
1972. **Preliminary results of hydrologic studies in southeastern Kansas coal fields.** Univ. Kans. State Geol. Surv. Spec. Distrib. Publ. 65: 24-26, illus. (1972 Mined Land Workshop Proc.)
Hydrologic reconnaissance in and around strip-mined areas showed that (1) the quality of groundwater in the spoil is rather poor, but it does have an alkaline pH; and (2) pond water is of better quality than spoil-bank water.

**U.S.-KS : coal-B : IV**

356. McCormick, Larry H., and F. Yates Borden.
1973. **Percolate from spoils treated with sewage effluent and sludge.** *In* Ecology and Reclamation of Devastated Land vol. 1: 239-250. Gordon and Breach Sci. Publ., New York.
Application of sewage-plant effluent and sludge singly and in combinations to spoils is discussed. Lysimeters were used to measure chemical changes of the percolate. The release of large quantities of ammonia, increase in pH, Ca, and K, and a decrease of S concentrations were related to the amount and method of application. The spoils have provided satisfactory renovation of most major chemical constituents of sludge and effluent.

**U.S.-PA : coal-B : III-B+VI-B**

357. McCreery, R. A.
1971. **Grasses and legumes useful for reclamation.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 87-88. Ga. Surface Mined Land Use Board. Macon.
Few sites are more drastically disturbed than those where highways are constructed. The author describes several treatments on highway cuts and fills in Georgia. Treatments consist of nurse and permanent species, along with added topsoil. Since the study was only one year old on half the sites, he lists observations rather than conclusions.

**U.S.-GA : other : VI-B**

358. McDougall, W. B.
1925. **Forests and soils of Vermillion County, Illinois, with special reference to the "striplands."** Ecology 6: 372-379.
The strip-mined bottomlands are first invaded by annual weeds. Under favorable conditions, forest is reestablished in about 24 years.

**U.S.-IL : coal-B : VI-B**

359. McKeever, Ivan.
1963. **Guide for classifying and revegetating strip mine spoil in Pennsylvania.** U.S. Soil. Conserv. Serv. 23 p., illus.
A classification of bituminous strip-mine spoils in Pennsylvania based on three factors: (1) degree of acidity, (2) slope, and (3) stoniness. Each of the factors is subdivided into groups. A guide for the vegetative species for each spoil group is suggested. Uses and planting guides are given for hayland and pasture, woodland, and wildlife.

**U.S.-PA : coal-B : III-A**

360. McQuilkin, William E.
1965. **Reclamation for aesthetics.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 97-105. University Park.
The author focuses attention on the concept of beautification of the country site which became a matter of national policy in the same manner as the conservation movement at the turn of the century. Discusses the White House Conference on National Beauty, a changing public attitude, community action, and industry cooperation in restoring esthetics in coal-mining regions.

**U.S. : coal : V-C+VII-A**

361. McWilliams, Jesse L.
1970. **Arnot bristly locust a new plant**

**for conservation and beautification in Pennsylvania.** U.S. Soil Conserv. Serv. 9 p., illus.

Arnot bristly locust planted on coal-mine spoils proved to be of value in providing protective cover on steep banks. Plant origin, growth habits, adaptation, use, and availability are described.

**U.S.-PA : coal-B : VI-B**

362. Magnuson, M. O., and R. L. Kimball.
1968. **Revegetation studies at three strip-mine sites in north-central Pennsylvania.** U.S. Bur. Mines R 7075. 8 p.

Revegetation tests were conducted at three backfilled strip-mine sites (El-Camton project). Trees, shrubs, and grass-legume mixtures were tested under various lime and fertilizer levels. Norway spruce, black locust, Japanese larch, pitch pines, and white pines performed best on sites with pH 4.5 and above. Grass-legume ground cover improved in the second growing season.

**U.S.-PA : coal-B : VI**

363. Martin, Cecil N.
1971. **Design and construction of eastern embankments used in establishing water supply or waste ponds.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 54-58. Ga. Surface Mined Land Use Board. Macon.

The discussion is limited to roll-filled dams with pipe drop inlet type principal spillway and vegetated earth emergency spillway. Various dam failures are explained as are surveys of area, site location, and subsurface investigations. Design factors, types of embankments, construction, and post-construction inspections are discussed.

**U.S.-GA : others : VIII**

364. Massey, H. F.
1972. **pH and soluble Cu, Ni, and Zn in eastern Kentucky coal mine spoils.** Soil Sci. 114 (3) : 217-221.

On the basis of studies with four spoil materials, the effects of liming on solution concentrations of Zn, Cu, and Ni can be estimated roughly from pH measurements. More accurate estimates could be obtained by making a few determinations on each spoil material. Of the three elements studied, Ni appeared to be most likely to remain in the soil solution in toxic amounts once the pH has been adjusted to a point which would otherwise be satisfactory for plant growth.

**U.S.-KY : coal-B : III-B**

365. Massey, H. F., and R. I. Barnhisel.
1971. **Copper, nickel, and zinc released from acid coal mine spoil materials of Eastern Kentucky.** Soil Sci. 113 (3): 207-212.

Appreciable concentrations of Ni, Cu, and Fr are found in coal-mine spoils. Possible toxicities from these elements must be considered by those involved in coal-mine spoil reclamation.

**U.S.-KY : coal-B : III-B**

366. May, Morton.
1967. **Mine reclamation in the western States.** Min. Congr. J. 53 (8) : 101-105.

Problems associated with mined-land reclamation in the western United States are reviewed and discussed. Lack of moisture, and the selection of suitable plant species, are the major problems. Research findings and needs are pointed out.

**U.S.-WY : coal, ore waste : VI-B**

367. May, Robert F.
1963. **Predicting outslopes of spoil banks.** USDA For. Serv. Res. Note CS-15. 4 p., illus. Cent. States For. Exp. Stn., Columbus, Ohio.

The slope length of the spoil bank is a function of the height of the highwall and the angle of the original mountain slope. The prediction equation is given.

**U.S.-KY : coal-B : III**

368. May, Robert F.
1964. **Surface-mine reclamation: continuing research challenge.** Coal Age March 1964: 98-99, 101, illus.

The problems and the research direction in revegetation, hydrology, earth movement and placement, soil mechanics, pyritic-material identification, mined-bank chemistry, and haulage roads are discussed.

**U.S.-KY : coal-B : VIII-C**

369. May, Robert F.
1965. **Strip-mine reclamation research —where are we?** Min. Congr. J. 51 (4): 52-55, illus.

A report on U.S. Forest Service research on coal-mine spoils reclamation through its project in Berea, Ky. Accomplishments are reviewed and present and future research objectives and demands are described.

**U.S.-KY : coal-B : VIII-C**

370. May, Jack T.
1971. **Selection and use of trees in reclamation.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 89-99. Ga. Surface Mined Land Use Board. Macon.

Research plantings on kaolin clay mining spoils indicate that loblolly, slash and Virginia pines, sycamore, sawtooth and white oak, and European black alder will survive and grow if adequately fertilized. Loblolly pine and sycamore have consistently given the best survival and growth.

**U.S.-GA : kaolin : VI-B**

371. May, J. T., H. H. Johnson, H. F. Perkins, and R. A. McCreery.
1973. **Some characteristics of spoil material from kaolin strip-mining.** *In* Ecology and Reclamation of Devastated Land vol. 1: 3-14. Gordon and Breach Sci. Publ., New York.

Spoils derived from kaolin-clay mining are characterized. Extreme variation in physical characteristics and in concentration of nutrient elements within small spoil segments were reported. The spoil contains 0 to 100 percent sand or 0 to 85 percent clay. Available P and exchangeable K, Ca, and Mg range from 2 to 160, 4 to 110, 6 to 600, and 2 to 600 ppm respectively. Ca and Mg are low except where lime material is present. P and K are low in all strata. Mn and Fe are most abundant in the upper strata.

**U.S.-GA, AL : kaolin : III**

372. May, Jack T., C. L. Parks, and H. F. Perkins.
1973. **Establishment of grasses and tree vegetation on spoil from kaolin clay strip-mining.** *In* Ecology and Reclamation of Devastated Land vol. 2: 137-147. Gordon and Breach Sci. Publ., New York.

Concentration of nutrients and the spoil pH are low. By using 908 kg of lime, 13.6 kg of N, 31.8 kg of P and 22.7 kg of K per ha, an excellent ground cover of grasses and lespedezas was established. Best tree species were loblolly pine, Virginia pine, sycamore, sawtooth oak, and black alder. Initial growth was poor, and foliar symptoms of nutrient deficiencies were evident when N and P were not applied at time of planting. High mortality occurred at first year in absence of fertilization.

**U.S.-AL : kaolin : VI-B**

373. May, Robert F., and William A. Berg.
1967. **Overburden and bank acidity — eastern Kentucky strip mines.** Coal Age 71: 74-75.

The pH of 831 samples of Pennsylvania age strata in the overburden of five coal seams was determined after grinding and then wetting and drying three times to oxidize sulfides. Seventy percent of the rider coal strata were extremely acid, compared with 40 percent of the bone coal, 7 percent of the shale, and 1 percent of the sandstone.

**U.S.-KY : coal-B : III-B**

374. May, Robert F., and W. David Striffler.
1966. **Watershed aspects of stabilization and restoration of strip-mined areas.** Int. Symp. Forest Hydrol. Proc.: 663-671. Pergamon Press, Oxford and New York.

Strip-mined mountain watersheds with 10 percent of the area disturbed have somewhat higher streamflows than adjacent forested watersheds. Small streams originating in

mined areas have a continuous flow whereas before mining they were intermittent. Erosion and sedimentation are attributed to sidecast overburden slides, haul roads, and the mined area itself. Water quality is affected by infiltration and percolation of water through the spoil. Proper spoil placement and adequate drainage control and revegetation are preventing serious erosion and pollution. Herb and tree plantings are effective in spoil stabilization.

**U.S.-KY : coal-B : IV-D**

375. Medvick, Charles.
1973. **Selecting plant species for revegetating surface coal mined lands in Indiana — a forty-year record.** *In* Ecology and Reclamation of Devastated Land vol. 2: 65-80. Gordon and Breach Sci. Publ., New York.

An analysis of a revegetation program of Indiana mining industries. Over 1 million trees are planted annually. Grass and legume species have also been used. Categories of overburden and recommended revegetation found to be successful are discussed.

**U.S.-IL : coal-B : VI-B**

376. Merz, Robert W.
1949. **Character and extent of land stripped for coal in Kentucky.** Univ. Ky. Agric. Exp. Stn. Circ. 66. 27 p., illus.

As of 1948, there were 7,267 acres of strip-mined lands in Kentucky. Approximately 80 percent of the stripped area was without vegetation; 46 percent of the area that had been stripped longer than 5 years was fully revegetated; 20 percent of the area stripped before 1942 had adequately stocked forest stands. About 15 percent of stripped lands were toxic to vegetation.

**U.S.-KY : coal-B : I-B**

377. Merz, Robert W., and Raymond F. Finn.
1951. **Differences in infiltration rates on graded and ungraded strip-mined lands.** USDA For. Serv. Cent. States For. Exp. Stn. Note 65. 2 p. Columbus, Ohio.

Mean infiltration rate on ungraded spoils was more than ten times greater than on graded spoils. Difference in mean volume weight was not significant.

**U.S.-OH : coal-B : III-C+IV-A**

378. Merz, R. W., and W. T. Plass.
1952. **Natural forestation on a strip-mined area in Ohio.** USDA For. Serv. Cent. States For. Exp. Stn. Note 68. 2 p. Columbus, Ohio.

Observation of natural reproduction on a strip-mined area indicates that natural seeding may satisfactorily reforest some areas near suitable seed sources.

**U.S.-OH : coal-B : VI-B**

379. Middour, J. C.
1950. **Reclamation of strip mined areas.** Pa. For. and Waters 2 (5): 98-99, 110-111, illus.

Reviews the development of strip-mining for coal in Pennsylvania. Presents some data on land disturbance as of 1950 and discusses some examples of successes and advantages of planting those areas with trees, shrubs, and grasses.

**U.S.-PA : coal-B : VI-B**

380. Miles, V. C., R. W. Ruble, and R. L. Bond.
1973. **Performance of plants in relation to spoil classification in Pennsylvania.** *In* Ecology and Reclamation of Devastated Land vol. 2: 13-31. Gordon and Breach Sci. Publ., New York.

Since the late 1930s, observations have been made on approximately 190 grasses, 72 legumes, 20 shrubs, 21 trees, and 9 other plants. Results of the performance of the major grass, legume, shrub, and tree species planted by soil and water conservation district cooperators in the Soil Conservation Service's plant-materials program are summarized. Performance of these plants is related to a spoil-classification system considering pH, slope, and stoniness.

**U.S.-PA : coal-B : VI-B**

381. Mohney, Franklin H.
1965. **The industry and regulatory laws —current and future.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 44-54. University Park.

A summary on development of surface mining and early reclamation programs. Regulatory legislation is compared for this type of mining in Pennsylvania, Illinois, Kentucky, and Ohio. Effect of the law in Pennsylvania, from the viewpoint of industry representatives, is discussed.

**U.S.-PA : coal-B : VIII-A**

382. Montgomery, Robert K.
1965. **The Kentucky program after one year.** Ky. Dep. Nat. Resour. Strip Mine Reclam. Symp. Proc.: 41-44. Frankfort.

Describes the organization of the Kentucky Department of Natural Resources and assesses reclamation work in the state.

**U.S.-KY : coal-B : VIII**

383. Moore, Cordell J.
1967. **National strip mine study.** Ky. Dep. Nat. Resour. Strip Mining Symp. 7 p. Frankfort.

Surface mining and its reclamation have become nation-wide problems. Federal guidance and assistance are needed. Apparent weaknesses and deficiencies in the state laws and regulations on surface mining are outlined, and a proposed program is suggested to be financed through federal funds to minimize the damage from past mining.

**U.S. : coal : VIII-A**

384. Morgan, G. W.
1973. **Crop productivity as affected by depths of topsoil spread for reclaiming bauxite-mined lands in Jamaica** I. Paper presented at the Conference on Soils of the Caribbean and Tropical America, Trinidad. 41 p.

Four soil-depth spreads (6, 12, 18, and 24 inches) used for reclaiming bauxite-mined lands, in combination with two fertilizer treatments and two cultivation treatments, were investigated. Treatments were evaluated by the yields of crops grown on the reclaimed land. Over the period 1969 to 1972 experiments were conducted with grass, maize, yellow yam, and sweet potato. It has been concluded that bauxite lands in Jamaica, which will be used for growing grass, maize, yams, or sweet potato, should be reclaimed with a 12-inch soil-depth spread, that the reclaimed land should not be ripped, and that high application of fertilizers should be profitable except for maize.

**Jamaica : bauxite : VI+VII-C**

385. Morgan, G. W.
1974. **Crop productivity as affected by depths of topsoil spread for reclaiming bauxite-mined lands in Jamaica.** Trop. Agric. (Trinidad) 51 (2) : 332-346.

Depths of soil spread for reclaiming bauxite-mined lands in combination with fertilization and cultivation were investigated. It was concluded that bauxite lands in Jamaica to be used for growing grass, maize, yams, or sweet potatoes should be reclaimed by spreading soil to a depth of 30 cm, that the reclaimed land should not be ripped, and that a high application of fertilizer should be profitable except for maize.

**Jamaica : bauxite : VI+VII-C**

386. Morgan, Herman, Jr., and W. L. Parks.
1967. **Reclamation of mined phosphate land.** Tenn. Agric. Exp. Stn. Bull. 416. 32 p. Knoxville.

Productive capacity of soil mined for phosphate was evaluated for growing agricultural crops. Responses to lime and fertilizer treatments are given. Physical and chemical properties of mined and unmined areas are discussed.

**U.S.-TN : phosphates : VII**

387. Morgan, R. L.
1973. **Environmental impact of surface mining: The biologist's viewpoint.** *In* Some environmental aspects of strip mining in North Dakota. N.D. Geol. Surv. Educ. Ser. 5: 61-71.

Surface mining has had little impact on fish

and wildlife resources. However, future large-scale operations could prove to be very detrimental to fish and wildlife resources.

**U.S.-ND : coal-L : VII-G**

388. Morris, Melvin S.
1974. **Coal versus a way of life in Eastern Montana.** Wildlands 1 (1) : 8-14, illus.
The author analyzes coal mining and its effect on the environment and discusses other land uses.

**U.S.-MT : coal-L : VIII**

389. Moulton, E. Q. [Ed.]
1957. **The acid mine drainage problem in Ohio.** Ohio State Univ. Eng. Exp. Stn. Bull. 166. 158 p.
This report presents the results of the research program in acid mine drainage. The research carried out included (1) mineralogic and geologic considerations, (2) acid formation studies, (3) an impoundment program, (4) the evaluation of the pollution problem on Sundy Run, (5) a mine scaling flooding program, and (6) utilization of gobs for lightweight aggregate. Findings that have the greatest implications pertinent to the acid mine drainage problem are emphasized. More than 500 annotated references on the subject of acid mine drainage are included.

**U.S.-OH : coal-B : IV+VII-E**

390. Mumford, R. E., and W. C. Bramble.
1973. **Small mammals on surface-mined land in southwestern Indiana.** *In* Ecology and Reclamation of Devastated Land vol. 1: 369-376. Gordon and Breach Sci. Publ., New York.
A study of small mammals on surface-mined land in southwestern Indiana indicated that mice were important factors in the ecosystem. The white-footed mouse was the most abundant. It consumed seeds of important trees as well as other plants on mined land. Five of the nine mouse species trapped comprise a significant segment of the wildlife food chain found on such areas.

**U.S.-IN : coal-B : VII-E**

391. Munn, Robert F.
1973. **Strip mining; an annotated bibliography.** W. Va. Univ. Library. 110 p. Morgantown.
This bibliography contains 611 citations, many annotated. Citations are listed in an alphabetical order (by authors) and are grouped into 6 chapters: history, government regulations, the controversy over stripping, environmental effects, reclamation, miscellaneous, and addenda.

**U.S. : coal : VIII-E**

392. Musser, John J.
1963. **Description of physical environment and of strip-mining operations in parts of Beaver Creek Basin, Kentucky.** U.S. Geol. Surv. Prof. Pap. 427-A. 25 p., illus.
Results of an investigation of the effects of strip-mining for coal on the hydrology of a portion of the Beaver Creek Basin, McCreary County, Kentucky. The report describes the topography, drainage geology, soils, climate, hydrologic environment, and forest vegetation of the study area and gives a history and description of the mining. Seven topographic maps are included.

**U.S.-KY : coal-B : I+IV**

393. Myers, Leroy O.
1950. **Bituminous coal stripping in West Virginia.** W. Va. Acad. Sci. Proc. 22: 98-100.
Brief history of the production of strip-mine coal in West Virginia.

**U.S.-WV : coal-B : VIII**

394. National Coal Association Bituminous Coal Research, Inc.
1973. **First research and applied technology symposium on mined-land reclamation.** Bitum. Coal Res., Inc. 355 p. Monroeville, Pa.
This volume is a product of the symposium held in March 1973 in Pittsburgh, Pa. It contains 30 papers given by workers well known in the field of reclamation of disturbed areas. The papers are grouped into six topics:

(1) innovative approaches to mining and reclamation, (2) pre-planning and mine operating procedures, (3) characterization and preparation of disturbed materials to enhance plant growth, (4) planting and plant materials, (5) slope stabilization and sediment control, and (6) utilization and management of mined lands.

**U.S. : coal : VIII-D**

395. National Sand and Gravel Association.
1961. **Case histories; rehabilitation of worked-out sand and gravel deposits.** 32 p. Silver Spring, Md.

Examples of successfully rehabilitated land after sand and gravel deposits have been excavated; pictorial presentation of case histories.

**U.S. : sand and gravel : VII**

396. Neckers, J. W., and Charles R. Walker.
1952. **Field test for active sulfides in soil.** Soil Sci. 74: 467-470, illus.

Describes a simple field test for sulfides and pyrites that could be used to predict future acidity in coal-mine spoils. The results in general correlate with total sulfur determined by laboratory methods.

**U.S. : coal-B : III-B**

397. Neumann, G. W.
1969. **Tailings disposal at Brunswick Mining and Smelting.** Can. Min. J. 90 (6) : 60-61.

A design for tailing storage and effluent settling ponds. Soluble Zn and Cu are removed by adding lime to increase pH to above 9.5.

**Canada : ore waste : VI**

398. Neumann, Ulrich.
1973. **Succession of soil fauna in afforested spoil banks of the brown-coal mining district of Cologne.** *In* Ecology and Reclamation of Devastated Land vol. 1: 335-348. Gordon and Breach Sci. Publ., New York.

In the reclaimed areas of the Cologne brown-coal mining district, a succession can be observed from raw spoil banks to approximately 30-year-old afforestations. The progress of succession of carabid beetles, millipedes, and woodlice was investigated. Many pioneer species and numbers of carabids are found on spoil banks. With the development of trees and other vegetation, these fauna are replaced by millipedes and woodlice. Microclimate is one of the most decisive factors in establishment of soil fauna.

**Germany : coal-L : VI-B**

399. Nielson, Rex F., and H. B. Peterson.
1973. **Establishing vegetation on mine tailings waste.** *In* Ecology and Reclamation of Devastated Land vol. 2: 103-115. Gordon and Breach Sci. Publ., New York.

Most copper tailings in the West are deficient in N and P; some are deficient in K. Uranium tailings are high in N because of ammonium hydroxide used in processing. Salinity is a problem; thus leaching is necessary before vegetation can be established. High acidity occurs in uranium tailings because of the addition of acid in milling. A number of plants have been well adapted to the adverse conditions. Several legumes will develop nodules and fix N if salinity and nutrient deficiencies are corrected.

**U.S.-UT : ore waste : III**

400. Noble, E. A.
1973. **A geologist's view of strip mining.** *In* Some environmental aspects of strip mining in North Dakota. N.D. Geol. Surv. Educ. Ser. 5: 53-60.

The geologist sees that strip-mining is a unique but relatively minor disturbance of a small portion of the earth's surface. In the context of human experience, the environmental effects of strip-mining have been offensive.

**U.S.-ND : coal-L : VIII-B**

401. Ohio State University and Ohio Academy of Science.
1964. **A symposium on strip-mine reclamation.** Ohio J. Sci. 64 (2) : 65-175.

This volume contains 10 papers presented at

the symposium on strip-mine reclamation, held at the Ohio Agricultural Experiment Station in Wooster, in August 1962.

**U.S.-OH : coal : VI+VIII-D**

402. Olschowy, Gerhard.
1973. **Landscape planning on an ecological basis.** *In* Ecology and Reclamation of Devastated Land vol. 2: 477-484. Gordon and Breach Sci. Publ., New York.

Surface mining interferes with the natural balance of the landscape. Agricultural lands and forests are encroached; water courses, roads, and railroads are shifted; farms and villages are relocated. Reclamation requires finding of facts before and during operations. The landscape diagnosis is prepared to assess damages from mining and the limitation for use after mining. Reclamation can restore lands to productivity and to create diversified spots of forest and lakes for recreation. The brown-coal district could serve as a model for future development in which the need of the economy, agriculture, recreation, and nature preservation are met equally.

**Germany : coal-L : VII**

403. Onosode, A. T., and J. F. Redhead.
1973. **The reclamation of land devastated by tin mining on the Jos Plateau, Nigeria.** *In* Ecology and Reclamation of Devastated Land vol. 2: 407-416. Gordon and Breach Sci. Publ., New York.

At 4,000 feet elevation, the 2,000-square-mile Jos Plateau of Nigeria is a dry land of seasonal rainfall. Historically, clearing forests, over-farming, and subsequent over-grazing have created severe damage. Surface mining for tin during the past 60 years has superimposed added problems. In the last 20 years the Mineland Reclamation Unit has successfully established eucalyptus plantations on leveled mine dumps. These plantations have improved landscape aesthetics, promoted a biological change in subsoils, and provided poles and firewood for local use.

**Nigeria : ore waste : VI**

404. Paller, William, and Donald A. Schultz.
1973. **Planning approaches to surface mining on the national forests.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 68-81. Bitum. Coal Res., Inc., Monroeville, Pa.

Phosphate mining in Caribou National Forest, Pocatello, Idaho, is related to the general problems of strip-mining. An administrative study by the Forest Service and four members of the phosphate mining industry considered reclamation of areas already mined and made plans for future mining to minimize effects of disturbing land. Surface mining is also considered in relation to multiple use of an area with nonrenewable resources and its impact on timber production, wildlife needs, water quality, fisheries, and groundwater supplies.

**U.S.-ID : phosphates : VI**

405. Parks, C. L., H. F. Perkins, and Jack T. May.
1967. **A greenhouse study of P and K requirements for ladino clover establishment on kaolin strip mine spoil.** Ga. Agric. Res. 9 (2) : 8-11, illus.

Ladino clover has been grown in kaolin strip-mine spoils in the greenhouse by adding lime, P, and K. Two tons of lime per acre raised the pH from 4.8 to 7.2; 70 pounds of P and 100 pounds of K were needed for good plant growth.

**U.S.-GA : kaolin : VI-B**

406. Parsons, F. W.
1906. **Coal mining by open stripping in Pennsylvania.** Eng. and Min. J. 81 (26) : 1239-1240.

A primitive strip-mining operation in the anthracite coal fields near Hazleton is described. Coal resources and economic considerations are discussed. Mining improvements are suggested.

**U.S.-PA : coal-A : II**

407. Pennsylvania, Commonwealth of.
1962. **Proceedings of the National Sym-**

**posium on Control of Coal Mine Drainage.** Pa. Dep. Health Publ. 4. 113 p.

This volume is a product of the symposium held in June 1962 in Pittsburgh. It contains papers on the status of law and legislation, technical aspects of control of drainage from active and abandoned mines, restoration of strip-mined lands, improvement of acid polluted streams, and administration of mine-drainage control programs. The volume includes numerous speeches, reports, and remarks related to the problem.

**U.S. : coal : VIII-D**

408. Perkins, H. F., and Patricia S. Troth. 1971. **Properties of drastically disturbed surface mined soils.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 37-41. Ga. Surface Mined Land Use Board. Macon.

A discussion of spoils resulting from strip-mining of kaolin clay. Kaolin overburden and spoil are diverse texturally, structurally, and in ability to hold moisture. They are generally acid and low in nutrients. Deficiencies in toxicities of micronutrients are not indicated. Kaolin spoil is undergoing soil formation as indicated by nutrient recycling.

**U.S.-GA : kaolin : III**

409. Peters, W. C. [Ed.] 1970. **Mining and ecology in the arid environment.** Univ. Ariz. Coll. Mines Conf. Proc. 229 p. Tucson.

A report on the conference on mining and ecology in the arid environment held in Tucson, Arizona, in March 1970. It contains 31 papers related to the subject. Extensive comments, questions, and answers are included. Some of the subjects and phenomena discussed in this volume are of nationwide importance.

**U.S. : ore waste, other : VIII-D**

410. Peterson, E. B., and H. M. Etter. 1970. **A background for disturbed land reclamation and research in the Rocky Mountain Region of Alberta.** Can. For. Serv. Dep. Fish. and For. Inf. Rep. A-X-34. 45 p.

The authors review current literature, describe operations and controls, and suggest principles and research objectives for reclamation of land disturbed by coal mining in the Rocky Mountain region of Alberta.

**Canada-AB : coal : VIII**

411. Peterson, Howard B., and Ralph Monk. 1967. **Vegetation and metal toxicity in relation to mine and mill wastes.** Utah State Univ. Agric. Exp. Stn. Circ. 148. 75 p. Logan.

An annotated bibliography of the literature dealing with the toxic elements found in mine, mill, and smelter wastes, and the toxic effects on vegetation. It lists 167 publications by 220 authors. Subject and author indexes.

**U.S. : ore waste : VIII-E**

412. Peterson, H. B., and Rex F. Nielson. 1973. **Toxicities and deficiencies in mine tailings.** *In* Ecology and Reclamation of Devastated Land vol. 1: 15-25. Gordon and Breach Sci. Publ., New York.

Various mine and mill wastes differ. Tailings from Cu, Pb, Zn, and U mills have one or more characteristics such as poor physical properties, toxic substances, nutrient deficiency, high acidity, or alkalinity and salinity. The oxidation of sulfides in Cu-wastes lower the pH and increase the solubility of several heavy metals. The problem associated with growing plants on Cu-tailings is related to low pH.

**U.S. : ore waste : III-B**

413. Peterson, J. R., and J.Gschwind. 1973. **Amelioration of coal mine spoils with digested sewage sludge.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 187-196. Bitum. Coal Res., Inc., Monroeville, Pa.

Acid mine spoils have been successfully reclaimed with digested sewage sludge. Application of 200 to 250 tons per acre resulted in a permanent grass cover, and the sub-

surface water quality was upgraded. Large acreage of calcareous spoils have been upgraded with sludge.

**U.S.-IL : coal-B : VI-B**

414. Plass, William T.
1966. **Land disturbances from strip-mining in eastern Kentucky. 1. Upper Cumberland Coal Reserve District.** USDA For. Serv. Res. Note NE-52. 7 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Results of an airphoto and field survey to determine the extent of land disturbance by coal mining and by coal-haul roads in Upper Cumberland Coal Reserve District. Describes the district's forest cover, physiography and geology, and distribution and physical characteristics of the 11,845 acres disturbed in this 434,000-acre district.

**U.S.-KY : coal-B : I-B**

415. Plass, William T.
1967. **Land disturbances from strip-mining in eastern Kentucky. 2. Princess Coal Reserve District.** USDA For. Serv. Res. Note NE-55. 8 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Results of an airphoto and field survey to determine the extent of land disturbance by coal mining and by coal-haul roads in Princess Coal Reserve District. Describes the district's forest cover, physiology and geology, and distribution and physical characteristics of the 4,761 acres disturbed in this 855,000-acre district.

**U.S.-KY : coal-B : I-B**

416. Plass, William T.
1967. **Land disturbances from strip-mining in eastern Kentucky. 3. Licking River Coal Reserve District.** USDA For. Serv. Res. Note NE-68. 6 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Results of an airphoto survey to determine the extent of land disturbances by coal mining and by coal-haul roads in Licking River Coal Reserve District. Describes the district, forest cover, physiography and geology, and distribution and physical characteristics of the 1,456 acres disturbed in this 1.1-million-acre district.

**U.S.-KY : coal-B : I-B**

417. Plass, William T.
1967. **Land disturbances from strip-mining in eastern Kentucky. 4. Big Sandy Coal Reserve District.** USDA For. Serv. Res. Note NE-69. 7 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Results of an airphoto survey to determine the extent of land disturbance by coal mining and by coal-haul roads in the Big Sandy Coal Reserve District. Describes the district, forest cover, physiography and geology, and distribution and physical characteristics of the acreage disturbed in this district.

**U.S.-KY : coal-B : I-B**

418. Plass, William T.
1967. **Land disturbances from strip-mining in eastern Kentucky. 5. Hazard Coal Reserve District.** USDA For. Serv. Res. Note NE-71. 7 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Results of an airphoto survey to determine the extent of land disturbance by coal mining and by coal-haul roads in Hazard Coal Reserve District. Describes the district, forest cover, physiography and geology, and distribution and physical characteristics of the acreage disturbed in this district.

**U.S.-KY : coal-B : I-B**

419. Plass, William T.
1967. **Land disturbances from strip-mining in eastern Kentucky. 6. Southwestern Coal Reserve District.** USDA For. Serv. Res. Note NE-72. 8 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Results of an airphoto survey to determine the extent of land disturbance by coal mining and by coal-haul roads in Southwestern Coal Reserve District. Describes the district, forest cover, physiography and geology, and distribution and physical characteristics of the acreage disturbed in this district.

**U.S.-KY : coal-B : I-B**

420. Plass, William T.
1967. **Survey of eastern Kentucky.** Ky. Dep. Nat. Resour. Strip Mining Symp. 6 p. Frankfort.

A review of the location and status of strip-mining disturbance and data obtained from the survey.

**U.S.-KY : coal-B : I-B**

421. Plass, William T.
1968. **Tree survival and growth on fescue-covered spoil banks.** USDA For. Serv. Res. Note NE-90. 4 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

A 2-year-old ground cover of tall fescue, K-31, did not affect survival of white pine, loblolly pine, sycamore, and sweetgum seedlings planted on strip-mine spoils in Kentucky, but reduced the height growth of the species as compared with growth on spoils free of cover.

**U.S.-KY : coal-B : VI-B**

422. Plass, William T.
1969. **Pine seedlings respond to liming of acid strip-mine spoil.** USDA For. Serv. Res. Note NE-103. 8 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

A greenhouse trial was made to determine the effects of liming on the growth of five species of pine seedlings in an extremely acid strip-mine spoil. Liming at the rate of 5 tons per acre-foot significantly increased the growth of four of the species. Tissue analysis indicated that the growth rate may be related to a reduction in the concentration of the metallic ions of Mn, Fe, Cu, and Zn.

**U.S.-KY : coal-B : VI-B**

423. Plass, William T.
1971. **Highwalls — an environmental nightmare.** W. Va. Univ. Symp. Reveg. and Econ. Use of Surf.-Mined Land and Mine Refuse Proc.: 9-13. Morgantown.

The highwall is the dominant physical feature of most auger and surface mining in mountainous terrain. This is a review of the problems and opportunities for highwall screening based on hypothetical situations. Some obvious problems in highwall screening have been identified. Research priorities can be assigned to these problems, and we have the framework for a research project.

**U.S.-WV : coal-B : VI-B**

424. Plass, William T.
1972. **Fertilization treatments increase black locust growth on extremely acid surface-mine spoils.** Tree Planters' Notes 23 (4) : 10-12.

Black locust seedlings planted on extremely acid spoils responded to P and N fertilizers during 3 years after planting.

**U.S.-KY : coal-B : VI-B**

425. Plass, William T.
1973. **Chemical soil stabilizers for surface mine reclamation.** *In* soil erosion: causes and mechanism, prevention and control. Highw. Res. Board Spec. Rep.: 118-122. Washington, D.C.

Successful stabilization of surface-mine spoils and other drastically disturbed areas depends on the establishment of vegetative cover. Mulches and soil stabilizers may be used on these sites to help establish vegetation and reduce erosion. In two cooperative demonstrations in West Virginia vegetation establishment and erosion were compared following 30 mulch and soil-stabilizer treatments. There was no evidence that these treatments were necessary for vegetation establishment. Large variations did occur in erosion losses between treatments.

**U.S.-WV : coal-B : VI**

426. Plass, William T.
1973. **Genetic variability in survival and growth of Virginia pine planted on acid surface-mine spoil.** *In* Ecology and Reclamation of Devastated Land vol. 1 : 493-507. Gordon and Breach Sci. Publ., New York.

Fifty-seven open-pollinated Virginia pine progeny from 10 natural stands widely dispersed throughout Tennessee and Kentucky were evaluated under field conditions. On an extremely acid spoil after two growing sea-

sons, survival, total height, and second-year growth were significantly better for some progeny. Greenhouse growth of 11 progeny did not correlate with growth under field conditions. Tissue analysis of the greenhouse-grown seedlings showed significant differences between progeny in nutrient uptake.

**U.S.-WV : coal-B : VI-B**

427. Plass, William T.
1974. **Factors affecting the establishment of direct-seeded pine on surface-mine spoils.** USDA For. Serv. Res. Pap. NE-290. 5 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

In a greenhouse study, the emergence, survival, and growth of seven species of pine were related to chemical and textural charactristics of 12 Kentucky spoils. The results were used to identify three factors that may affect the establishment of direct-seeded pine on surface-mine spoils: (1) fine-texturd spoil material may restrict seedling emergence; (2) species vary in their response to chemical and physical characteristics of the spoil material; and (3) the growth of loblolly pine was greatest where the percentage of phosphorus in the whole plant was greatest.

**U.S.-KY : coal-B : III+VI-B**

428. Plass, William T., and James D. Burton
1967. **Pulpwood production potential on strip-mined land in the South.** J. Soil and water Conserv. 22 (6) : 235-238, illus.

Wherever extensive areas of strip-mined land lie within the procurement area of a pulpmill there is an opportunity for coal and paper companies to cooperatively plan reclamation programs for plupwood production.

**U.S.-KY : coal-B : VII-D**

429. Plass, William T., and John P. Capp.
1974. **Physical and chemical characteristics of surface mine spoil treated with fly ash.** J. Soil and Water Conserv. 29 (3) : 119-121.

Use of power-plant fly ash for surface-mine reclamation offers an attractive outlet for large amounts of this waste. The authors describe changes that occurred in a spoil following the application of 150 tons of fly ash per acre. The treatment neutralized acidity, added plant-available P, lowered spoil density, and increased subsurface moisture.

**U.S.-WV : coal-B : III**

430. Plass, William T., and Willis G. Vogel.
1973. **Chemical properties and particle-size distribution of 39 surface-mine spoils in southern West Virginia.** USDA For. Serv. Res. Pap. NE-276. 8 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

A survey of 39 surface-mine sites in southern West Virginia showed that most of the spoils from current mining operations had a pH of 5.0 or higher. Soil-size material averaged 37 percent of the weight of the spoils sampled. A major problem for the establishment of vegetation was a deficiency of nitrogen and phosphorus. This can be corrected with additions of fertilizer at appropriate rates.

**U.S.-WV : coal-B : III-B**

431. Paluch, Jan, Ed.
1965. **Materialy Sympozjalne.** Pol. Acad. Sci. Symp. Proc. B. 302 p. Katowice.

This volume contains 44 papers (16 in Russian and 28 in English) presented at the Second International Symposium dealing with the problems of reclamation of industrial lands, held in October 1965 in Katowice, Poland. The papers deal primarily with the ecology and reclamation of disturbed lands in member countries of the Mutual Economic Assistance Committee of Eastern Europe.

**Europe : coal : VIII-D**

432. Potter, H. Spencer, Sidney Weitzman, and George R. Trimble, Jr.
1951. **Reforestation of strip-mined lands in West Virginia.** USDA For. Serv. Northeast. For. Exp. Stn. Pap. 43. 28 p.

The authors discuss the conditions pertaining to plant growth that prevail in West Virginia; the nature and extent of natural revegetation; condition of existing tree and shrub plantings; and the effects of acidity,

texture, and spoil age on performance of tree species.

**U.S.-WV : coal-B : VI-B**

433. Pratt, Parker F., Eamor S. Nord, and Francis L. Bair.
1971. **Early growth tolerances of grasses, shrubs, and trees to boron in tunnel spoil.** USDA For. Serv. Res. Note PSW-232. 5 p. Pac. Southwest. For. and Range Exp. Stn., Berkley, Calif.

The effects of B in spoil material on survival and growth of 44 grass, strub, and tree species were tested under greenhouse conditions. The spoil used was from the Angeles Tunnel being built for the California Aqueduct's West Branch. Several species within each plant group apparently can tolerate B, but field tests will be needed before most of them can be recommended for widespread plantings.

**U.S.-CA : other : III-B+VI-B**

434. Pyles, Hamilton K.
1965. **National forest policy on surface mining.** Ky. Dep. Nat. Resour. Strip Mine Reclam. Symp. Proc.: 36-40. Frankfort.

A report on the "White House Conference on Natural Beauty," emphasizing the work of the panel on "Reclamation of the Landscape."

**U.S. : coal : VIII-A**

435. Pyles, Hamilton K.
1965. **National implications — the coal regions.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 1-6. University Park.

Discusses the national attention on the restoration of natural beauty in coal regions. The White House Conference on Natural Beauty panel recommendations on rehabilitation of coal-mine spoils and the passage of the Appalachia Regional Development Act are reviewed.

**U.S. : coal : VIII-A**

436. Rainey, Kenneth D.
1965. **A regional approach to planning and development is necessary to the solution of the problems of the coal regions.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 7-11. University Park.

A need for a regional approach to the solution of the coal regions' problems: highway construction, combating water pollution, and healing the mining scars. The Appalachian Regional Development program is designed to solve some of those problems of the coal region.

**U.S. : coal : VIII-A**

437. Ramsey, John P.
1970. **Control of acid pollution from coal refuse piles and slurry lagoons.** Coal Mine Drain. Res. Symp. 3 Proc.: 138-144. Bitum. Coal Res., Inc., Monroeville, Pa.

Describes a demonstration project on the control of acid pollution from coal refuse piles and slurry lagoons. Small watersheds were created on a refuse pile and systems for data collection and interpretation of acid formation and water quality were established. To minimize the movement of air and water into the pyrite, by sealing, certain test plots received 40 tons/acre of lime and were seeded to grasses or treated with polyethylene plastic membrane, top soil, or dried sewage sludge. The effectiveness of the restoration on water quality will be studied. An excellent stand of grass was developed on limed and fertilized plots. The lagoons will be restored by planting a vegetative cover.

**U.S.-IL : coal-R : VI-B**

438. Reilly, James D.
1965. **Planning surface mine reclamation before mining.** Min. Congr. J. 51 (11): 93-96.

A need for a planning of reclamation before mining is stressed. Economics, revegetation, erosion, water conservation, and aesthetics as well as the potential land uses for recreation, forage, timber, and urban development must be considered.

**U.S.-OH : coal-B : VII**

439. Repp, Gertraud.
1973. **Cytoecological investigations with regard to the mechanism of chemical resistance of plants.** *In* Ecology and Reclamation of Devastated Land vol. 1: 445-466. Gordon and Breach Sci. Publ., New York.

Cell-physiological resistance tests of protoplasm may be of value in the revegetation of chemically adverse sites. When such sites are to be revegetated, these tests can be used as a rapid method for preliminary selection of suitable species. Plasmatic salt-tolerance test results agreed well with the results of field tests. Within the genetic limits of a species, plasmatic resistance is variable that offers possibilities for "hardening" against damaging site factors.

**Austria : other : VI-B**

440. Research Committee on Coal Mine Spoil Revegetation in Pennsylvania.
1965. **A guide for revegetating bituminous strip-mine spoils in Pennsylvania.** (Rev. 1971). 46 p., illus.

This guide provides a review and summary of knowledge about revegetation of bituminous strip-mine spoils in Pennsylvania, including legislation, characteristics and classification of spoils; and revegetation planning and reclamation for agricultural, wildlife, and recreational uses. Appedixes include a blibliography.

**U.S.-PA : coal-B**

441. Riley, Charles V.
1957. **Reclamation of coal strip-mined lands with reference to wildlife plantings.** J. Wildl. Manage. 21: 402-413.

The performance of 37 plant species useful to wildlife was evaluated. Bicolor and serecia lespedeza were most successful on various spoils. Korean lespedeza did very well on calcareous materials. Clover proved to be very successful. Alsike clover grew well in moist depressions. Mixed seeding of legumes and grasses did well on spoils with pH from 4.5 to 7.0. Scotch broom and Indigobush made excellent growth. Conifers growing in pure and mixed stands provided good cover. Black locust was superior to all other hardwood species.

**U.S.-OH : coal-B : VI-B+VII-E**

442. Riley, Charles V.
1965. **Limnology of acid mine water impoundments.** Acid Mine Drain. Res. Symp. 1 Proc.: 175-187. Bitum. Coal Res., Inc., Monroeville, Pa.

A progress report of research on limnological conditions of mine water impoundments. Analyses of watershed spoil material as compared with adjacent undisturbed land and the data on water quality in several ponds are presented. Tolerance of fish to the various chemical and physical components of mine water is also discussed.

**U.S.-OH : coal-B : IV-H+V-B+VII-E**

443. Riley, Charles V.
1972. **Design criteria of mined land reclamation.** Soc. Mech. Eng. Proc. Oct. 1972. 19 p.

To insure successful reclamation of mixed lands, knowledge and appreciation of the following criteria are essential: geochemistry of the overburden, spoil placement, grading for proper topography and spoil surface, all relative to improved site conditions needed for the successful establishment of vegetation, spoil stabilization, erosion control, and water management. The criteria should be considered as a part of the active mining operation, if the reclamation is to result in environmental improvement.

**U.S.-OH : coal-B : III+VI**

444. Riley, Charles V.
1973. **Chemical alterations of strip-mine spoil by furrow grading — revegetation success.** *In* Ecology and Reclamation of Devastated Land vol. 2: 315-331. Gordon and Breach Sci. Publ., New York.

A study was made of furrow-graded versus conventional smooth-graded spoils. Analyses revealed extremely high levels of metal ions, sulfates, and soluble salts, and pH values ranging from 3.1 to 4.1. Plant performance was better in the ravines than on the slopes,

ridges, or smooth-graded spoils. Analyses showed: a higher pH for ravine sites; higher levels of soluble salts in the ridge site; and higher levels of sulfates, Mn, Cu, and Zn in the ridges. Marked site improvement resulted, and reclamation was enhanced by the modified furrow grading technique.

**U.S.-OH : coal-B : III-B+VI-A**

445. Riley, Charles V.
1973. **Furrow grading—key to successful reclamation.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 159-177. Bitum. Coal Res., Inc., Monroeville, Pa.

The effectiveness of a furrowed spoil surface in improving the mined-land's ability to support vegetation was evaluated. Initial spoil analysis revealed high levels of soluble salts, sulfates, and metal ions, and a pH range of 3.1 to 4.1. Data from ridge and ravine samples showed a higher pH and lower levels of soluble salts for the ravine sites, and higher levels of Mn, Cu, and Zn in the ridge and smooth surface sites. Ca, Mg and K, $NO_3$, and $NH_3$ were in greater amounts in ridges of smooth surfaces. Furrowing created a surface conducive to water retention, absorption, and infiltration. Site improvement was also reflected by better plant performance in the ravines than on the ridges or on the smooth surfaces.

**U.S.-OH : coal-B : III-B+VI-A**

446. Riley, Charles V., and James A. Rinier.
1972. **Reclamation and mine tip drainage in Europe.** Coal Mine Drain. Res. Symp. 4 Proc.: 1-14. Bitum. Coal Res., Inc., Monroeville, Pa.

An overview of the study of problems associated with the reclamation of coal and lignite tips in western Europe, mainly in Great Britain and in West Germany.

**Germany : coal-L : VI**

447. Roberts, John R.
1971. **Grading and slopes used in reclamation.** Rehabil. of Drastically Disturbed Surf. Mined Lands Symp. Proc.: 47-50. Ga. Surface Mined Land Use Board. Macon.

A fairly comprehensive review of coal strip-mining and reclamation methods and state regulations in Kentucky. The author discusses both contour and area stripping. His description of contour stripping is broken down into different types of cuts and grading methods and final stability of the fills.

**U.S.-KY : coal-B : II-B+VI**

448. Robinson, Robert C.
1971. **Management of surface waters, erosion control and soil stabilization techniques.** Rehabil. of Drastically Disturbed Surf. Mined Lands Symp. Proc.: 51-53. Ga. Surface Mined Land Use Board. Macon.

The mechanics of erosion are complex. Surface-mined land offers more severe conditions than most other lands, but the problems are the same. By judicious use of vegetation, terraces, diversion channels, outlets and ponds, or sediment basins it should be feasible to adequately control erosion.

**U.S.-GA : kaolin : IV-E**

449. Rogers, Nelson F.
1949. **The growth and development of black walnut (*Juglans nigra* L.) on coal strip-mined land in southeast Kansas.** Kans. Acad. Sci. Trans. 52 (1): 99-104, illus.

The 12- to 14-year results show that plantations can be established on certain spoils by the planting of seeds. Trees make satisfactory growth, produce seeds, and yield logs and veneer bolts in a reasonable time.

**U.S.-KS : coal-B : VI-B**

450. Rogers, Nelson F.
1951. **Strip-mined lands of the western interior coal province.** Mo. Agric. Exp. Stn. Res. Bull. 475. 55 p., illus.

A summary of results of the survey on condition of coal strip-mined lands in Arkansas, Oklahoma, Kansas, Missouri, and Iowa. Data on spoil acidities, available nutrients, and organic matter. Area of strip-mined lands,

list of tree species found, and other data are presented in an appendix.

**U.S. : coal-L : III+VII**

451. Roll, William H.
1962. **A short description of Kentucky coals.** Univ. Ky. Eng. Exp. Stn. Bull. 17 (1). 35 p., illus.

A summary description of Kentucky coals, by coal fields and seams. Characteristics of coal are given.

**U.S.-KY : coal-B : I-A**

452. Roseberry, John L., and W. D. Klimstra.
1964. **Recreational activities on Illinois strip-mined lands.** Soil and Water Conserv. 19 (3) : 107-110.

More than 4,000 acres of land are being excavated annually for open-cut mining in Illinois. A portion of the resulting spoil areas might be developed to meet increasing needs for recreational space. Current use of the more than 108,000 acres of strip-mined land in the state, and the recreational use now being made of it, are described.

**U.S.-IL : coal-B : VII-F**

453. Rothwell, Frederick M.
1973. **Nodulation by various strains of *Rhizobium* with *Robinia pseudoacacia* seedlings planted in strip-mine spoil.** *In* Ecology and Reclamation of Devastated Land vol. 1: 349-353. Gordon and Breach Sci. Publ., New York.

Sixteen strains of *Rhizobium* were studied for their ability to nodulate black locust seedlings. Three of the bacterial strains were effective in all spoil types, and two strains modulated in three of the four spoil materials where the seedlings were grown under controlled conditions. The use of planting-bullet studies is proposed as an effective technique for studies of rhizosphers as well as symbiotic and mycorrhizal microorganisms of tree species used to revegetate the spoils.

**U.S.-KY : coal-B : III-D+VI-B**

454. Ruble, Ralph W.
1965. **A review of "A guide for revegetating bituminous strip-mine spoils in Pennsylvania."** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 106-110. University Park.

A review of the material presented in the "Guide for revegetating bituminous strip-mine spoils in Pennsylvania," published in 1965. (The guide was revised in 1971.)

**U.S.-PA : coal-B : VI**

455. Ruffner, Joseph D.
1962. **New plants for Alleghenies; strip mine spoils and shale soils.** Soil Conserv. 27 (9) : 209-210, illus.

Chemung and Pendleton crownvetch, Garrett County narrowleaf trefoil, Blackwell switchgrass, and Indian grass are new plants suitable for highly erodible mine spoils.

**U.S.-WV, MD, PA : coal-B : VI-B**

456. Ruffner, Joseph D.
1965. **Adaptation and performance of shrubs in mine spoil reclamation.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 117-123. University Park.

A research summary on shrub-type plants that have been evaluated on coal-mine spoils, with a list of shrubs for spoil reclamation in Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Virginia, and West Virginia. according to spoil-acidity classes.

**U.S. : coal-B : VI-B**

457. Ruffner, Joseph D.
1966. **An evalution of species planted on coal strip mine spoil in West Virginia for stabilization purposes, 1955 to 1965.** W. Va. Univ. 28 p. Morgantown.

A summary of results from 10 years of species evaluations by the Soil Conservation Service in West Virginia. Grasses, legumes, trees, and shrubs are included.

**U.S.-WV : coal-B : VI-B**

458. Ruffner, Joseph D.
1973. **Projecting the use of new plant**

**materials for special reclamation problems.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 233-242. Bitum. Coal Res., Inc., Monroeville, Pa.

Knowledge of the site and of the plants to be used are essential for successful revegetation of spoils. The SCS has developed a vegetative species guide based on spoil classification. Spoils are classified by reaction, degree of slope, texture, and stoniness. Selection of grasses, legumes, and tree species depends on the land use intended and on site characteristics. New plant material is evaluated as to its range of adaptability. Exposure, spoil compaction, amount of precipitation, and nutrient requirements should also be considered in revegetation of strip-mined land.

**U.S. : coal-B : VI-B**

159. Ruffner, Joseph D., and W. W. Steiner.
1973. **Evaluation of plants for use on critical sites.** *In* Ecology and Reclamation of Devastated Land vol. 2: 3-12. Gordon and Breach Sci. Publ., New York.

The authors discuss a program of SCS for developing plants useful for vegetating critical areas. Three major steps are involved: (1) plants are assembled, screened, and repropagated; (2) on-site planting and evaluation for site conditions; (3) evaluation to confirm performance and range adaptation. In the last 10 years more than 15 species and varieties have been confirmed for specific use on critical areas in the Northeast.

**U.S. : coal-B : VI-B+VIII-C**

460. Sall, George W.
1967. **Reclaiming strip-mined land in Washington.** W. Va. Coal Min. Inst. Proc.: 1-6.

Comments relating to proposed federal surface-mining legislation.

**U.S. : coal-B : VIII-A**

461. Sandoval, F. M., J. J. Bond, J. F. Power, and W. O. Willis.
1973. **Lignite mine spoils in the northern great plains — characteristics and potential for reclamation.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 117-133. Bitum. Coal Res., Inc., Monroeville, Pa.

Lignite and subbituminous coal spoils were studied to evaluate their potential for reclamation. Results show that the spoil materials provide a very poor environment for plant growth. Materials were extremely fine textured (Montmorillonitic), moderately saline, and highly sodic. Severity of the problems associated with high clay and high adsorbed Na content increase with depth from the original surface. Low organic matter combined with fine texture enhance the Na dispersion effect, which renders the spoil materials unstable, highly impermeable, and erodible. Available P was very low and N varied, depending on spoil age. Fertilization (P) in combination with the use of topsoil and straw mulches showed promise for reclamation. Response to gypsum has been very slow.

**U.S. : coal-L : III-B+VI-B**

462. Sandoval, F. M., J. J. Bond, J. F. Power, and W. O. Willis.
1973. **Lignite mine spoils in the northern great plains — characteristics and potential for reclamation.** *In* Some environmental aspects of strip mining in North Dakota. ND Geol. Surv. Educ. Ser. 5: 1-24.

Chemical and physical properties of spoils provide a poor environment for vegetative growth. They are often fine textured, moderately saline, and highly sodic. Low organic matter and fine texture enhance the sodium dispersion effect, which renders the spoil unstable, impermeable, and erodible. Available P is very low, and N is variable. P fertilization in combination with topsoil, straw mulches, and gypsum are highly beneficial in reclamation work.

**U.S.-ND, MO : coal-L : III**

463. Saperstein, Lee W., and Edwin S. Secor.
1973. **Improved reclamation potential with the block method of contour stripping.** Res. and Appl. Tech. Symp. on

Mined-Land Reclam. Proc.: 1-14. Bitum. Coal Res., Inc., Monroeville, Pa.

The block method of mining, which has been used successfully in strip mining on hillsides, is described in detail. Mining is carried out in sections so that overburden from an area being mined can be placed in a mined-out area as mining proceeds. Overburden handling can be planned so that acid-producing soil can be segregated, and buried and topsoil can be reserved for final spreading. A cursory investigation of the economics of the block method indicates that it is no more expensive and may costs less than conventional dragline mining.

**U.S. : coal-B : II-B**

464. Sargent, Thomas N.
1971. **Protection of streams and lakes and adjacent lands from mining and related industrial waste.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 59-64. Ga. Surface Mined Land Use Board. Macon.

Mining and related industrial activities are potentially a great source of pollution to streams and lakes. Some of the problems to be solved include solids handling and disposal and the leaching of pollutants from mining activities. The Environmental Protection Agency administers a research program directed toward solving some of these problems.

**U.S. : coal, other : VIII**

465. Sauer, Elmer L.
1962. **Trends in economics of mined area restoration.** *In* conservation — a key to world progress. Soil Conserv. Soc. Am. Proc. Pap. 108-D: 107-119. Des Moines, Iowa.

A report on the findings of a survey on cost of and possible returns from restoring mined areas. Summaries are presented by states, based on information provided by industry and reclamation associations. Examples of projects developed in several states are given.

**U.S. : coal : VI**

466. Sawyer, L. E.
1946. **Indiana strip-mine plantings.** J. For. 44: 19-21.

Reforestation of the spoil piles that follow the open-cut mining of coal in Indiana has been under way since 1926. Many species of trees, both softwoods and hardwoods, have been tried. Under a plan approved by the Indiana Coal Producers Association in September 1944, all lands owned by member companies will hereafter be devoted to their highest use.

**U.S.-IN : coal-B : VI-B**

467. Sawyer, L. E.
1949. **The use of surface mined land.** J. Soil and Water Conserv. 4 (4): 161-165, 170.

The author reviews the development of revegetation programs based on land-use research, starting in the early 1920s. Studies referred to show that survival and growth of trees planted on leveled areas were markedly less than on unleveled areas. The rate of water infiltration on unleveled areas was higher than on leveled areas.

**U.S.-IN : coal-B : VI-B**

468. Sawyer, L. E.
1962. **Restoration of areas affected by coal mining.** Symp. Control of Coal Mine Drain. Proc. Nat. Pa. Dep. Health Publ. 4: 52-58.

The problems of restoring strip-mined lands are summarized. Discussion includes brief history of early reforestation efforts, research, spoil characteristics and species selection, planting stock and methods, grading effects, and land use for recreation and homesites.

**U.S. : coal-B : VI+VII-D**

469. Sawyer, L. E.
1962. **Mined area restoration in Indiana.** J. Soil and Water Conserv. 17 (2): 65-67.

An analysis of the problem and a progress report on restoration of coal strip-mine spoils to some form of productive use. Research

needs, effects of grading, and tree growth progress in Indiana are discussed.

**U.S.-IN : coal-B : VI**

470. Scanlon, David H., Carroll Duggan, and S. D. Bean.
1973. **Evaluation of municipal compost for strip mine reclamation.** Compost Sci. 14 (3) : 4-8.

The use of municipal compost in the reclamation of highly acid strip-mine spoils was tested. Heavily composted plots showed a decrease in acidity and developed an organic layer that stabilized the surface. Good herbaceous cover was established without the addition of fertilizers or lime.

**U.S.-VA : coal-B : VI-B**

471. Schavilje, Joseph P.
1941. **Reclaiming Illinois strip mined coal lands with trees.** J. For. 39: 714-719.

In Illinois about 100 square miles of land have been or eventually will be stripped in mining coal. Although these areas are a small percentage of the total land area of the state, they are ugly scars on the landscape. Largely through the leadership of the Illinois Division of Forestry, the mine operators have undertaken a program of planting stripped areas. This work has been under way for some years, and the results so far obtained are reported here.

**U.S.-IL : coal-B : VI-B**

472. Schimp, Park E.
1973. **Deep-mine waste reclamation experimentation in the bituminous regions of Pennsylvania.** *In* Ecology and Reclamation of Devastated Land vol. 2: 457-467. Gordon and Breach Sci. Publ., New York.

Trees, perennial grasses, and annuals were seeded to determine germinative capacity. Trees and shrub seedlings were planted to establish utility of various planting procedures and fertilizing methods. It was found that internal heat as a result of burning spots within the bank, erosion, and sulfur gas injury played only minor roles in the high mortality rates experienced in the past. High solar radiation absorption and low moisture combined to desiccate plant tissue during critical periods. Switchgrass, weeping lovegrass, yucca, bristly locust, and Virginia pine demonstrated hardness to the site. Fertilizing and planting with water-soaked vermiculite had no significance in first-year survival.

**U.S.-PA : coal-B+R : III+VI-B**

473. Schlatzer, Georg.
1973. **Some experiences with various species in Danish reclamation work.** *In* Ecology and Reclamation of Devastated Land. vol. 2: 33-64. Gordon and Breach Sci. Publ., New York.

Plantations on Danish dune areas, heathlands, and strip-mine spoils were established to test native and foreign wood species for use in wildlife plantations, reclamation work, and landscape plantings. The Desert Arboretum plantation covers 20 ha. of strip-mine spoils. It has 460 wood species, of which conifers form but a small fraction. Techniques used, some experiences in amelioration, and examples from the wide range of species planted are discussed.

**Denmark : coal, other : VI-B**

474. Schmehl, W. R., and B. D. McCaslin.
1973. **Some properties of spent oil-shale significant to plant growth.** *In* Ecology and Reclamation of Devastated Land vol. 1: 27-43. Gordon and Breach Sci. Publ., New York.

Analyses of the spent shale revealed that the material was alkaline, saline, and low in available P and N. There was little growth in wheatgrass and ryegrass in untreated shale. When the shale was mixed with soil, growth of the crop did increase, but on the 50:50 soil-shale mixture it was still less than 10 percent of that on natural soil. When soluble salts were removed from the spent shale by leaching, normal plant growth could be obtained after fertilizing with N and P.

**U.S.-CO : other : III-B+VI-B**

475. Schmidt, J. W., and K. Conn.
1969. **Abatement of pollution from mine wastewaters.** Can. Min. J. 90 (6): 54-60.
A report on an investigation of generation of acid within the tailings pond system and effluent-receiving stream of a base metal mine. The processes of acid generation and the possible treatment methods of wastes are discussed.

**Canada-NB : ore waste : V-B**

476. Schramm, J. R.
1966. **Plant colonization studies on black wastes from anthracite mining in Pennsylvania.** Am. Philos. Soc. Trans. (n.s.) 56 (1). 194 p., illus.
A synthesis of findings related to the basic problems in establishment of vegetation on coal-breaker refuse banks and silt basins in the Anthracite Region, based on 24 years of experimentation and observation. Effects of moisture, wind, frost, acidity, surface temperature and the role of mycorrhizal relationships in plant growth are discussed.. Temperature effects, nutrient deficiencies, and the function of micorrhizate deserve special attention.

**U.S.-PA : coal-A+R : III+VI-B**

477. Seastrom, Paul N.
1965. **New land orchards.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 129-141. University Park.
A story of successful establishment of orchards on stripped lands. The new land can grow high-quality fruit. Prior knowledge of horticulture is essential. Sites should be graded, easily accessible, and located adjacent to a smooth-surfaced road to prevent damage to fruit. Fruit varieties depend on market demands and location.

**U.S.-IL : coal-B : VII-C**

478. Seidel, Kenneth W.
1961. **Seeded black walnut taller than planted walnut on Kansas spoil banks.** USDA For. Serv. Cent. States For. Exp. Stn. Note 148. 1 p. Columbus, Ohio.
Direct-seeded black walnut trees survived as well as and grew faster than planted trees for 10 years on Kansas spoil banks.

**U.S.-KS : coal-B : VI-B**

479. Seidel, Kenneth W., and Kenneth A. Brinkman.
1962. **Mixed or pure walnut plantings on strip-mined land in Kansas?** USDA For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 187. 10 p., illus. Columbus, Ohio.
In mixed plantings with black locust, black walnut survival, growth, and form were impaired. When planted with other species (burr oak, sycamore, red cedar, and green ash), however, walnut grew almost as well as in pure stands. Mixed plantings are recommended because they usually result in better trees.

**U.S.-KS : coal-B : VI-B**

480. Shetron, Stephen G., and Ralph Duffek.
1970. **Establishing vegetation on iron mine tailings.** J. Soil and Water Conserv. 25 (66): 227-230.
Grasses and legumes have been established successfully on fertilized iron mine tailings. Performance of trees was poor. Fine textured layers within the plant rooting zone were beneficial for grass and legume establishment.

**U.S.-MI : ore waste : III+VI-B**

481. Singer, Philip, C., and Werner Stumm.
1970. **Acidic mine drainage: the rate determining step.** Science 167 (3921): 1121-1123.
Oxidation of ferrous iron is the rate-determining step in the oxidation of iron pyrite and the formation of acidity in streams associated with coal and copper mines. Effective pollution abatement necessitates controlling this reaction.

**U.S. : coal, ore waste : V-B**

482. Sitterley, J. H.
1964. **Future land use in the Appalachian Plateau and its relation to strip-mine reclamation.** Ohio J. Sci. 64 (2): 106-111.

A projection of land use in the Ohio segment of the Appalachian Plateau for two decades in the future. Land-use in 1980 will be characterized by less land in farms, more strip-mined land, and more land in water reservoirs, highways, parks, and forest. The relationship of land use in 1980 to strip-mine reclamation will be little different from what it is today. The change will arise from the need for watershed protection, pollution control, and recreation.

**U.S.-OH : coal-B : VII**

483. Smith, Edwin E., Kenesaw S. Shumate, and Karlis Svanks.
1968. **Sulfide to sulfate reaction studies.** Coal Mine Drain. Res. Symp. 2 Proc.: 1-11. Bitum. Coal Res., Inc., Monroeville, Pa.

Investigations designed to point out the physical and chemical parameters related to the kinetics of the sulfide-to-sulfate reaction are described. A mechanism is suggested to explain the observed kinetics.

**U.S.-OH : coal-B : IV-G+V-B**

484. Smith, Gordon E.
1968. **Swatara Creek watershed abatement project.** Coal Mine Drain. Res. Symp. 2 Proc.: 236-245. Bitum. Coal Res., Inc., Monroeville, Pa.

The author describes steps taken to control water pollution caused by mine drainage flowing into tributary streams of the Swatara Creek watershed. Apparent improvement in the water quality was observed, due to a decrease in sulfate, iron, and acid concentrations.

**U.S.-PA : coal-A : VI+IV**

485. Smith, H. G., H. H. Morse, G. E. Bernath, L. E. Gillogly, and W. M. Briggs.
1964. **Classification and revegetating of strip-mine spoil banks.** Ohio J. Sci. 64 (2) : 168-175.

The authors discuss the classification of strip-mine spoils for purposes of determining suitable land-use planning conditions and planting practices used by the U.S. Soil Conservation Service in strip-mine reclamation.

**U.S.-OH : coal-B : III-A+VI-B**

486. Smith, John M.
1971. **Spoil placement and use to meet reclamation requirements.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 42-46. Ga. Surface Mined Land Use Board. Macon.

The author discusses briefly the surface and strip-mining of kaolin in Georgia. He cites requirements for different pieces of equipment, cost of equipment, and economics of overburden removal. He describes different stripping methods and preparation of reclamation sites for their intended end use.

**U.S.-GA : kaolin : II**

487. Smith, R. M., E. H. Tryon, and E. H. Tyner.
1971. **Soil development on mine spoil.** W. Va. Univ. Agric. Exp. Stn. Bull. 604 T. 47 p., illus. Morgantown.

Physical, chemical, and biological characteristics of iron ore spoils in West Virginia were compared with those of natural soils. Soils were superior in bulk density, porosity, structure, infiltration, N or organic matter, texture, and smoother land surface. Spoils were superior in depth for plant rooting, water-holding capacity, available P, and more gentle slopes. Forest site quality and minerology did not differ greatly. Spoils may be equal or superior for perennial plants and primary legumes, but are likely to be inferior for annual or perennial crops sensitive to N deficiencies.

**U.S.-WV : ore waste : III+VI-B**

488. Soil Conservation Society of America.
1962. **Conservation — a key to world progress.** Soil Conserv. Soc. Am. Annu. Meet. Proc. 17: 85-119.

Collection of papers dealing with the reclamation of strip-mined lands, presented at the annual meeting of the society.

**U.S. : coal : VI**

489. Sopper, William E.
1970. **Revegetation of strip mine spoil banks through irrigation with municipal sewage effluent and sludge.** Compost Sci. 11 (6) : 6-11.

Municipal sewage effluent and sludge were applied as amendment to bituminous coal-mine spoils. Beneficial effects on establishment of vegetation are reported.

**U.S.-PA : coal-B : VI-B**

490. Sopper, William E., and Louis T. Kardos.
1972. **Municipal wastewater aids revegetation of strip-mined spoil banks.** J. For. 70: 612-615.

Municipal wastewater and sludge applied to highly acid coal-mine spoils were effective in establishing a ground cover of grasses and legumes. Performance of forest trees, both conifers and hardwoods, was markedly improved. Chemical characteristics of percolate are given.

**U.S.-PA : coal-B : VI-B**

491. Stephan, Robert W., and Walter C. Lorenz.
1967. **A review of current research on coal mine drainage in Appalachia.** U.S. Bur. Mines. 26 p. Pittsburgh, Pa.

The status of research on methods for the abatement or control of acid mine drainage. A literature review contains 67 annotated references.

**U.S. : coal : V-B**

492. Stephan, Robert W., and Walter C. Lorenz.
1968. **Survey of costs on methods for control of acid mine drainage pollution.** U.S. Bur. Mines. 35 p.

A summary of cost data for coal mine reclamation, with emphasis on acid mine drainage control.

**U.S. : coal : V-B**

493. Striffler, W. David.
1965. **The selection of experimental watersheds and methods in disturbed forest areas.** Budapest Symp. Int. Assoc. Sci. Hydrol. 2: 464-473. Ghentbrugge, Belgium.

Watershed research techniques and their application to problems on mechanically disturbed watersheds are discussed. Some of the methods are being used to evaluate the effects of surface mining on the hydrology of forested watersheds.

**U.S.-KY : coal-B : VII-B**

494. Striffler, W. David.
1967. **Restoration of open-cast coal sites in Great Britain.** Soil and Water Conserv. 22 (3) : 101-103, illus.

Open-cast mines in Great Britain are physically similar to strip-mines in the United States, but disturbed areas are generally smaller. Restoration of these areas is discussed, along with costs of reclamation.

**Great Britain : coal-B : VI**

495. Striffler, W. D.
1973. **Surface mining disturbance and water quality in eastern Kentucky.** *In* Ecology and Reclamation of Devastated Land vol. 1: 175-191. Gordon and Breach Sci. Publ., New York.

Surface mining for coal in eastern Kentucky has disturbed thousands of acres of mountain land. Land mined in this manner is frequently considered a major source of acid pollution. A survey of 180 fourth-order and larger watersheds during the summer of 1966 indicated that very little acid pollution occurs in the larger streams; however, acid pollution may be a serious problem on small severely disturbed watersheds.

**U.S.-KY : coal-B : V-B+VIII-B**

496. Striffler, W. David, and Robert F. May.
1965. **Forest restoration of strip-mined areas.** Proceedings, Soc. Am. For. Proc. 1965: 105-108, illus.

Area and contour-type strip-mining are described. Effects of strip-mining on streamflow, erosion and sedimentation, quantities of

dissolved solids, and problems of restoring mined lands to forest are discussed.

**U.S.-KY : coal-B : II-B+VII-D**

497. Struthers, Paul H.
1960. **Forage seedings help reclaim acres of spoil banks.** Ohio Farm and Home Res. 45 (1) : 12-13.

Forage species—legumes and grasses—have been used successfully in revegetation efforts.

**U.S.-OH : coal-B : VII-C**

498. Struthers, Paul H.
1961. **180,000 stripmine acres: Ohio's largest chemical works.** Ohio Farm and Home Res. 46 (4) : 52-53.

A report on the quality and quantity of chemicals leached from strip-mined spoils at various acidity levels, in comparison with natural soils. Salts leached from spoils range from 20 to more than 200 times the amount leached from natural soils.

**U.S.-OH : coal-B : III-B**

499. Struthers, P. H.
1964. **Chemical weathering of strip-mine spoils.** Ohio J. Sci. 64 (2) : 125-131.

Quantitative analytical data on chemical weathering of coal-mine spoils. Intensive weathering began immediately upon exposure to air and water; large quantities of sulfate salts were produced in the top layer; highest salt concentrations occurred in late summer and fall; soluble mineral nutrients were more abundant in spoils than in soils; salt production was not related to spoil pH, and it decreased after the first year. Toxic spoils are characterized by very high acidity, very high salt content, high levels of soluble Al, Fe, and Mn, and by limited amounts of Ca and Mg.

**U.S.-OH : coal-B : III-B**

500. Struthers, P. H.
1965. **Rapid spoil weathering and soil genesis.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 86-90. University Park.

Man can modify spoil conditions to accelerate the processes of soil formation by grading and planting. A general discussion on spoil modification due to weathering and biological action.

**U.S.-OH : coal-B : VI-A**

501. Struthers, P. H.
1965. **Influence of weathering on strip mine drainage.** Acid Mine Drain. Res. Symp. 1 Proc.: 161-166. Bitum. Coal Res., Inc., Monroeville, Pa.

Quantitative data about the rate, magnitude, and kinds of changes occurring in strip-mine spoil during physical and chemical weathering. Weathering conditions the spoil for plant growth and accelerates soil formation. The chemistry of strip-mine drainage reflects the chemical changes caused by spoils weathering.

**U.S.-OH : coal-B : III-B+IV-F**

502. Struthers, Paul H., and J. P. Vimmerstedt.
1965. **Rapid strip mine reclamation.** Ohio Rep. 50 (6) : 84-87. Ohio Agric. Res. and Dev. Cent., Wooster.

The amount of drainage and its solute content depend on rain percolation. Salt yields decreased in dry years and the solute concentration increased. The increased drainage is more dilute and flushes out a greater total amount of solute. Weathering processes and biochemical changes are essential in transforming spoil to soil.

**U.S.-OH : coal-B : IV-F+VI-A**

503. Struthers, P. H., and J. P. Vimmerstedt.
1965. **Advances in strip mine reclamation.** Ohio Rep. 50 (1) : 3-5. Ohio Agric. Exp. Stn., Wooster.

Better reclamation can be gained by planting both forages and trees. Terrace grading was beneficial for promoting rain infiltration and leaching, and for controlling erosion.

**U.S.-OH : coal-B : IV-A+VI-A**

504. Sturgill, William B.
1965. **Strip mine reclamation under the**

**1964 act (eastern Kentucky).** Ky. Dep. Nat. Resour. Strip Mine Reclam. Symp. Proc.: 4-8. Frankfort.

Discusses the possibility of establishing orchards on strip-mine spoils.

**U.S.-KY : coal-B : VII-C**

505. Sullivan, G. Don.
1967. **Current research trends in mined-land conservation and utilization.** Min. Eng. 19 (3) : 63-67, illus.

A review of the research on mined-land reclamation currently under way. The work is centered in the Eastern States, with some interest and research starting in the Midwest. Areas of interest include revegetation, spoil chemistry, hydrology, and earth movement.

**U.S. : coal : VIII-C**

506. Sutton, Paul.
1970. **Restoring productivity of coal mine spoil-banks.** Ohio Rep. 55 (4) : 62-63. Ohio Agric. Res. and Dev. Cent., Wooster.

A use of soil, limestone, mulch, and subsoiling to loosen the spoils are suggested for reclaiming toxic spoils. The research conducted at the Ohio Research and Development Center is described.

**U.S.-OH : coal-B : VI-B+VII-C**

507. Sutton, Paul.
1973. **Reclamation of toxic stripmine spoilbanks.** Ohio Rep. 58 (1) : 18-20. Ohio Agric. Res. and Dev. Cent., Wooster.

Furrow-grading of toxic spoils did not result in establishing vegetation, but a covering with nontoxic spoil was beneficial in establishing sweet clover and lespedeza.

**U.S.-OH : coal-B : III-B+VI-B**

508. Sutton, Paul.
1973. **Establishment of vegetation on toxic coal mine spoils.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 153-158. Bitum. Coal Res., Inc., Monroeville, Pa.

Toxic spoils were covered with soil suitable for plant growth, limestone was used to neutralize acidity, organic materials such as sewage sludge and cattle manure were added, and different plant species were used. It seems that toxic coal-mine spoils can be vegetated by these methods. The plant root systems will be confined to the zone of the cover or mixing of the material. The results to date indicate that a period of several years will be required before there will be enough improvement in the untreated portion of the highly pyritic soils to support plant roots.

**U.S.-OH : coal-B : VI-B**

509. Sutton, P., and J. P. Vimmerstedt.
1973. **Treat stripmine spoils with sewage sludge.** Ohio Rep. 58 (6) : 121-123. Ohio Agric. Res. and Dev. Cent., Wooster.

Applications of sewage sludge were highly beneficial in establishing a grass ground cover on acid mine spoils.

**U.S.-OH : coal-B : VI-B**

510. Sutton, P., and J. P. Vimmerstedt.
1974. **Treat strip mine spoils with sewage sludge.** Compost Sci. 15 (1) : 22-23, illus.

Application of sewage sludge proved effective in obtaining plant cover. In addition, the sludge increased P and K levels and increased the infiltration of rainwater, and runoff and erosion of sediment were reduced.

**U.S.-OH : coal-B : VI**

511. Tennessee Valley Authority.
1963. **An appraisal of coal strip mining.** TN. Val. Auth. 13 p. Knoxville.

Survey findings and an appraisal of the effects of strip-mining and the evaluation of reclamation efforts in the Appalachian and Midwestern coal fields.

**U.S. : coal-B : I+VI**

512. Tennyson, Gerald R.
1962. **Equipment development for strip mining and reclamation.** *In* Conservation —a key to world progress. Soil Conserv. Soc. Amer. Proc.: 99-105. Des Moines, Iowa.

A review of the current methods of mining and reclamation and the equipment used. The machine of the future is the mine-o-matic, powered by atomic energy and equipped with electronic sensing devices, computers, a T.V. monitoring, and other electronic equipment.

**U.S. : coal : II-A**

513. Thirgood, J. V.
1952. **The afforestation of colliery spoil heaps.** Coedwigr. 2 (1) : 10-18.
Reclamation of colliery spoil heaps by establishing forest is suggested. Classification and examination of site, treatment, planting methods, selection of species, after-establishment treatment, and economic aspects are discussed.

**Great Britain : coal-R : III-A + VII-D**

514. Thirgood, J. V.
1969. **Land disturbance and revegetation in Canada.** Can. Min. J. 90 (12) : 33-37, illus.
A review of problems related to land disturbance due to mining for coal, oil, iron, and other minerals as well as to non-mining disturbances. Damages and restoration efforts are discussed.

**Canada : coal, other : V**

515. Thirgood, J. V.
1969. **Production and reclamation planning, Kaiser Resources Limited.** Proc. 21st Can. Conf. on Coal Proc. 21 : 28-36, illus. Calgary.
The author describes the coal-mining operations and reclamation-planning program at the Crowsnest mining operation in British Columbia.

**Canada-BC : coal-L : VI**

516. Thirgood, J. V.
1970. **Land reclamation in Canada.** Commonw. For. Rev. 49 (3) : 141, 227-234.
Problems related to land disturbance due to mining for coal, oil, iron, and other minerals as well as non-mining disturbances, and damages and restoration efforts are discussed.

**Canada : coal, ore waste : V**

517. Thirgood, J. V.
1970. **The planned reclamation of mined lands.** W. Miner 43 (6) : 22-25.
A guide to preparation of reclamation plans according to mining laws of British Columbia. Placement of the overburden and revegetation methods are discussed.

**Canada-BC : coal : II + VIII**

518. Thirgood, J. V.
1971. **The rehabilitation of the mining environment in British Columbia.** Can. Min. and Metal. Bull. August 1971 : 1-6.
A review of legislation and its implementation as it relates to coal mining in British Columbia. Technical and organizational problems of reclamation are discussed, and techniques and experiences are described.

**Canada-BC : coal : VIII-A**

519. Thirgood, J. V.
1971. **Reclamation at Kitsault.** W. Miner 44 (3) : 54-57.
Discusses the mining operation, extent of land disturbance, and actual and planned reclamation of a mining community.

**Canada-BC : ore waste : VI**

520. Thirgood, J. V.
1973. **Planned Reclamation.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc. : 92-97. Bitum. Coal Res., Inc., Monroeville, Pa.
Reclamation should start with planning the mining operation to minimize dirt handling and assure availability of original topsoil as final cover. Other considerations in a reclamation program are, "the previous and intended use of the mined land and surrounding area, the topography, the potential of the soil for supporting vegetation, the available mining equipment, the regional economy, human settlement and resource use patterns

(current and projected), and the legal requirements."

**Canada-BC : coal : VI**

521. Thirgood, J. V., and W. F. Gilmore.
1971. **An approach to land reclamation at the Lornex mining project.** W. Miner 1971: 48-51, illus.

Potential land disturbance due to mining of copper and molybdenum ores, and the ways in which the reclamation is being tackled on the Lornex holdings in British Columbia, are described.

**Canada-BC : ore waste : VIII**

522. Thirgood, J. V., and J. R. Matthews.
1971. **Progress in reclamation research in British Columbia during 1970.** For. Chron. 47 (6) : 1-3.

An overall review of reclamation work in British Columbia.

**Canada-BC : coal : VI**

523. Thirgood, J. V., and M. D. Meagher.
1972. **Progress in reclamation research by mining companies in British Columbia during 1971.** For. Chron. 48 (6) : 308-311.

This report up-dates the status of reclamation of surface-mined lands in British Columbia. It is based on reports submitted by the industries.

**Canada-BC : coal, other : VI**

524. Thompson, Donald N., and R. J. Hutnik.
1972. **Environmental characteristics affecting plant growth on deep-mine coal refuse banks.** Pa. State Univ. Sch. For. Res. Briefs 6 (2) : 22-25.

Steep slopes, unstability, coarseness, high surface temperature, and unfavorable chemical characteristics are the common detrimental factors affecting the plant colonization of deep mine coal refuse banks.

**U.S.-PA : coal-B+R : III**

525. Thor, Eyvind, and James S. Kring.
1964. **Planting and seeding of loblolly pine on steep spoil banks.** J. For. 62 (8) : 575-576, illus.

Planted loblolly pine survived better than direct-seeded trees. Both planted and seeded trees grew faster on spoils with southern exposure.

**U.S.-TN : coal-B : VI-B**

526. Thurn, Edward A.
1952. **The potentialities of revegetating and utilizing agronomic species on strip mined areas in Illinois.** Univ. Ill. Agric. Exp. Stn. and Ill. Coal Strippers Assoc. 6th Yr. Prog. Rep. 48 p., illus.

This report on investigations of the potentialities of revegetating strip-mined lands with agronomic crops covers the first year of a new 3-year project designed to study basic principles of agronomic species on *graded* strip-mined land. Included in this report is a study of some physical and chemical properties of graded spoils, including analyses of highway strata and spoil permeability. Species-adaptation trials on graded spoils include forage crops as well as grain.

**U.S.-IL : coal-B : III+VII-C**

527. Townsend, W. N., and D. R. Hodgson.
1973. **Edaphological problems associated with deposits of pulverized fuel ash.** *In* Ecology and Reclamation of Devastated Land vol. 1: 45-56. Gordon and Breach Sci. Publ., New York.

Pulverized fuel ash (PFA), resulting from the burning of pulverized coal consists of silica and alumina (ca. 75%), Fe oxides (ca. 10%), alkaline earth elements (ca. 6%), alkali metals (ca. 5%), S (ca. 1%), traces of most other naturally occurring elements, and a small amount of unburned carbon. Physically it is in the coarse silt range and consists mainly of glassy particles. The edaphological problems involve (1) plant nutrients, (2) toxic factors, and (3) its physical nature of ash. The ash has adequate K, is low in P, contains no N, and has adequate micronutrients. High pH, excessive salinity, and water-soluble B result from hydrolysis during weathering. Pozzolanic activity is exhibited

during settling, curtailing plant establishment.

**Great Britain : fuel ash : III-B**

528. Trimble, George R., Jr.
1963. **Hybrid poplar grows poorly on acid spoil banks at high elevations in West Virginia.** USDA For. Serv. Res. Note NE-7. 4 p., illus.

Describes the performance of hybrid poplar on limed and unlimed strip-mine spoils after 3rd and 11th growing season. Lime treatment improved survival and height growth, but overall results were disappointing.

**U.S.-WV : coal-B : VI-B**

529. Tryon, E. H.
1952. **Pasture cover for spoil banks.** *In* Science Serves Your Farm. W. Va. Univ. Agric. Exp. Stn. Bull. 357 (2) : 5, 16.

The productivity of two old iron-ore spoil banks was compared to adjacent fields by counting desirable forage plants and dry-weight yields. Both spoil areas were more productive than the adjacent fields.

**U.S.-WV : ore waste : VII-C**

530. Tryon, E. H., and Rudolf Marcus.
1953. **Development of vegetation on century-old iron-ore spoil banks.** W. Va. Univ. Agric. Exp. Stn. Bull. 360. 63 p., illus.

Iron ore spoil banks, 72 to 131 years old, were studied to document vegetation, species composition, growth, and density. A comparison was made with adjacent undisturbed land.

**U.S.-WV : ore waste : VI-B**

531. Turner, William R.
1958. **The effects of acid mine pollution on the fish population of Goose Creek, Clay County, Kentucky.** Prog. Fish-Cult. 20 (1) : 45-46.

A ratio in a fish population in an unpolluted creek portion versus the one polluted by acid mine drainage was 12:1 respectively. Economic loss due to fish kill was calculated at $800 per 1 mile of stream.

**U.S.-KY : coal-B : V-B+VII-G**

532. Tyner, Edward H., and Richard M. Smith.
1945. **The reclamation of the strip-mined coal lands of West Virginia with forage species.** Soil Sci. Soc. Am. Proc. 10: 429-436, illus.

Based on active acidity of the surface layer, the spoils of nothern West Virginia were classified into three types. The properties of spoils are discussed. Factors determining successful plant growth, including use of lime, fertilizers, and manure and the adaptability of various forage species for growth on strip-mine spoils, were reported.

**U.S.-WV : coal-B : III-A+VI-B+VII-C**

533. Tyner, Edward H., Richard M. Smith, and Sidney L. Galpin.
1948. **Reclamation of strip-mined areas in West Virginia.** J. Am. Soc. Agron. 40: (4), 313-323, illus.

Delaying reclamation 1 and 3 years on pyrite-containing spoils reduced the amount of lime needed. Spoil surface is compacted in regrading to depth of 18 to 24 inches. Taprooted legumes, alfalfa, sweetclover, birdsfoot trefoil, and sericea lespedeza penetrate the compacted layers and contributed to breaking up the surface compaction and increasing the permeability of spoil to water, air, and fibrous roots of other species.

**U.S.-WV : coal-B : III-B+VI-B**

534. U.S. Bureau of Mines.
1973. **Methods and costs of coal refuse disposal and reclamation.** U.S. Dep. Inter. Inf. Circ. 8576. 36 p., illus.

Costs of refuse disposal, spreading, compacting, covering with soil, and planting, as reported by six mining companies and the Commonwealth of Pennsylvania.

**U.S.-PA : coal-B+R : VIII-B**

535. U.S. Department of Agriculture.
1968. **Restoring surface-mined land.** USDA Misc. Publ. 1082. 18 p., illus.

A summary of extent of land disturbance by strip and surface mining in the United States as of 1965. Broad characteristics and physical conditions of disturbed land are discussed. U.S.D.A. participation in reclamation of surface-mined land, the accomplishments, and the principles for a national surface-mined land conservation effort, are pointed out.

**U.S. : coal, other : VI**

536. U.S. Department of Interior.
1965. **Proposed outline of report required on strip and surface mining in the United States as authorized under P.L. 89-4, Section 205, Appalachian Region Development Act of 1965.** 55 p.

The report requires the following: nature and extent of strip and surface mining; ownership of real property (surface and/or mineral); the public interest in and public benefits from reclaiming surface-mined lands; role of federal, state, and private interests; objective of total overall costs of reclamation and rehabilitation program in the United States.

**U.S. : coal : VIII-A**

537. U.S. Department of Interior.
1966. **Study of strip and surface mining in Appalachia.** Interim Report by Secretary of Interior to Appalachian Regional Com. 78 p. Washington.

This report summarizes the findings of the Secretary of Interior on those aspects of strip-mining operations in the Appalachian Region that are urgently in need of attention. The goals are: "to prevent future devastation of the environment while fostering economic growth of the mineral industry and to alleviate damage caused by past strip and surface mining operation." Tables, maps, charts, and appendixes.

**U.S. : coal : VIII**

538. U.S. Department of Interior.
1967. **Surface mining and our environment.** U.S. Gov. Printing Office, Washington. 124 p.

This volume is a product of a study by a team of experts on surface mining and its effects in the United States, as required by P.L. 89-4. It includes: surface mining, its nature, extent and significance; impact on environment; related problems; yesterday's achievements; tomorrow's goals; the law and surface mining; and recommendations. Appendix includes numerous statistical tables; state strip- and surface-mining laws; and the miscellaneous federal statistics related to mining on federal lands.

**U.S. : coal, other : VIII**

539. U.S. Environmental Protection Agency.
1971. **Mine spoil potentials for water quality and controlled erosion.** EPA Water Pollut. Control Res. Ser. Proj. 14010 EJE 12/71. 207 p.

This report provides extensive information about geology, soil, chemistry, microbiology, and conservation of present and future coal-mine spoils in West Virginia. It provides a basis for applying those interrelated disciplines to discover and formulate solutions as related to water-quality problems at present and in the future.

**U.S.-WV : coal-B : III+IV**

540. U.S. Environmental Protection Agency.
1973. **Processes, procedures, and methods to control pollution from mining activities.** EPA-430/9-73-011. 390 p., illus. Washington.

Information about processes, procedures, and methods for controlling pollution resulting from mining. Cost-data estimates for control measures are given. An extensive bibliography is appended.

**U.S. : coal, other : V**

541. U.S. Forest Service.
1962. **Strip-mine reclamation—a digest.** (Rev. 1964) USDA For. Serv. East. Reg. and Soil Conserv. Soc. Am. 69 p.

The 1962 edition is a digest of literature published through mid-1961. The 1964 edition

includes a review and summary of literature up to 1964. The coverage includes a discussion of spoil characteristics and the effects these have on selection of plant species and planting methods. Potential uses of strip-mined lands and mining methods are discussed. The stringencies and administration of strip-mine reclamation legislation by individual states in eastern United States is reviewed.

**U.S. : coal : VI**

542. U.S. Soil Conservation Service.
1969. **Kanawha Basin comprehensive study: land stabilization problems area study, Coal River sub-basin and adjacent watersheds.** U.S. Soil Conserv. Serv. 22 p. Princeton, W. Va.

The results of two short-term studies initiated on two watersheds of the Coal River in West Virginia to evaluate soil erosion and sedimentation from surface mining. Treatments and additional studies are proposed for surface-mined areas and refuse piles.

**U.S.-WV : coal : IV-E**

543. University of Newcastle upon Tyne.
1971-1972. **Landscape reclamation.** Vol. 1, 135 p., and vol. 2, 85 p., illus. IPC Sci. and Tech. Press Ltd., Guildford, Surrey, England.

A two-volume report on reclamation of derelict lands in Great Britain, based on the research conducted by a team of the University of Newcastle. Topics covered are: vol. 1 — landscape reclamation; previous technique; research sites; landform design; earthworks; special problems; soil-forming materials; botanical studies of natural and planted vegetation; practical techniques for establishing vegetation; estimating and cost control and visual assessment of reclaimed landscape; vol. 2 — use, establishment and development of reclaimed landscape; development and maintenance organizations; legal and financial aspects of management; development and management of soil on pit heaps; drainage and erosion control; ground cover; long-term management of grass and tree plantations; the invertebrate fauna; development and appearance of reclaimed sites; and organization and future of research into landscape reclamation.

**England : coal, other : VI**

544. Usui, Hiroshi, and Heima Suzuki.
1973. **Ecological and revegetational problems of the Ashio devastated area.** *In* Ecology and Reclamation of Devastated Land vol. 2: 395-406. Gordon and Breach Sci. Publ., New York.

An area of 2500 ha in the vicinity of the Ashio copper mine has been damaged by $SO_2$. The devastation is due to $SO_2$ damage to the vegetation and to severe soil erosion. For revegetation purposes a "vegetation plate" was devised. It is a pressed plate of soil with fertilizer on which seeds are sown. The plates were arranged horizontally in rows on the eroded slopes. Weeping lovegrass — an exotic and a domestic species *Miscanthus sinensis* — were used. Both grasses thrived well for a few years, but later declined in vigor. *Clethra barbinervis* is the only dominant species of the secondary forest.

**Japan : ore waste : VI-B**

545. Van Landingham, A. H.
1965. **Mined area restoration today.** J. Soil and Water Conserv. 20 (4) : 185-186.

A digest on strip-mine rehabilitation problems and the factors affecting reclamation.

**U.S. : coal : VI**

546. Van Lear, David H.
1971. **Effects of spoil texture on growth of K-31 tall fescue.** USDA For. Serv. Res. Note NE-141. 7 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Growth of K-31 tall fescue was significantly affected by the texture of four spoils from eastern Kentucky. Growth on spoils having no toxic chemical properties was greatest where texture consisted of about equal amounts of soil-size material and a coarser fraction (2.0 to 6.4 mm), probably because moisture and aeration were favorable. On two spoils, adverse chemical properties modi-

fied the effect of physical properties associated with texture. Toxic levels of Mn in the smaller size fraction probably reduced yields on one spoil. On another the effect of texture was marked by toxic levels of Al in each of the three particle-size fractions.

**U.S.-KY : coal-B : III+VI-B**

547. Vimmerstedt, J. P.
1970. **Stripmine reclamation.** Ohio Rep. 55 (4) : 60-61. Ohio Agric. Res. and Dev. Cent. Wooster, Ohio.

A digest of the most important recent research findings.

**U.S.-OH : coal-B : VI**

548. Vimmerstedt, John P., and James H. Finney.
1973. **Impact of earthworm introduction on litter burial and nutrient distribution in Ohio strip-mine spoil banks.** Soil Sci. Soc. Am. Proc. 37 (3) : 388-391.

Earthworms introduced on acid spoils consumed or buried large quantities of black locust leaf litter and humus. Exchangeable cations and available P in the mineral spoils increased. Earthworm activity did not affect growth of northern red oak seedlings planted in the cores. Introduced on a calcareous spoil revegetated with European alder, the earthworm population increased drastically.

**U.S.-OH : coal-B : III-D+VI-A**

549. Vimmerstedt, John P., and Paul H. Struthers.
1968. **Influence of time and precipitation on chemical composition of spoil drainage.** Coal Mine Drain. Res. Symp. 2 Proc.: 152-163. Bitum. Coal Res., Inc., Monroeville, Pa.

Eight-year results of chemical characteristics of leachates percolating through the weathering columns of four spoil classes — toxic, marginal, acid and calcareous. Leachate volumes, total soluble salts, sulfate, Ca, Mg, Fe, Al, and Mn were determined. Effects of time and amount of precipitation are discussed.

**U.S.-OH : coal-B : III-B**

550. Vogel, Willis G.
1970. **Weeping lovegrass for vegetating strip-mine spoils in Appalachia.** First Weeping Lovegrass Symp. Proc.: 152-162. Samuel Roberts Noble Found., Ardmore, Okla.

Weeping lovegrass is more tolerant of extremely acid spoils, dry sites, and summer growing conditions than most of the commonly used cool-season grasses and legumes. It grows well in mixtures with slowly developing long-lived grasses or legumes. It provides quick cover during the first growing season and does not crowd out the companion species. When sown with black locust, it is less competitive with locust seedlings. N and P fertilizers are needed for its establishment on many spoils.

**U.S.-KY : coal-B : VI-B**

551. Vogel, Willis G.
1971. **Needs in revegetation research on surface-mined lands.** W. Va. Univ. Symp. Revegetation and Economic Use of Surface-Mine Refuse. Proc.: 17-18. Morgantown.

Revegetation research is needed for erosion control and for restoring or developing land uses. Specific needs include studies concerned with quick establishment of cover throughout the growing season, tree-grass competition, soil organisms, spoil amendments and fertilizer, and development of spoil for forest, pasture, wildlife habitat, and other uses. But most urgent is a need for research aimed at preventing problems of extreme acidity and instability.

**U.S.-KY : coal-B : VI-B**

552. Vogel, Willis G.
1973. **The effect of herbaceous vegetation on survival and growth of trees planted on coal-mine spoils.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 197-207. Bitum. Coal Res., Inc., Monroeville, Pa.

Establishing both trees and herbaceous vegetation is often desirable in the reclamation of strip-mine spoil banks. To study the effect

of herbaceous competition with trees, grass alone and grass with legumes were sown concurrently with the planting of four tree species on coal-mine spoils in southeastern Kentucky. After three growing seasons, the herbaceous vegetation, which had produced about 95 percent ground cover, did not significantly affect the survival of trees, but greatly suppressed their growth. However, in the fourth and fifth growing seasons, the growth of trees in the plots dominated by the legume exceeded the growth in plots with grass only and without herbaceous competition. Tree growth was suppressed the most by a cover of grass alone.

**U.S.-KY : coal-B : VI-B**

553. Vogel, W. G., and W. A. Berg.
1968. **Grasses and legumes for cover on acid strip-mine spoils.** J. Soil and Water Conserv. 23 (3) : 89-91, illus.

A vegetative cover is needed on most strip-mine spoils immediately after mining to reduce erosion and sedimentation. Field and greenhouse studies have shown that fertilized weeping lovegrass provided faster cover on extremely acid spoils (pH 4.0 to 4.5) than any other perennial grass or legume tested. Even the more acid-tolerant legumes grew poorly and did not nodulate in most of the acid spoils with pH below 4.5.

**U.S.-KY : coal-B : III-B+VI-B**

554. Vogel, Willis G., and William A. Berg.
1973. **Fertilizer and herbaceous cover influence establishment of direct-seeded black locust on coal-mine spoils.** *In* Ecology and Reclamation of Devastated Land vol. 2: 189-198. Gordon and Breach Sci. Publ., New York.

Phosphorous is the limiting element in many spoils for the early growth of direct-seeded black locust. By fertilizing with 49 kg/ha of P, the first year's height of locust was increased fourfold, and higher P rates produced even greater growth. Warm-season herbaceous species seeded with the locust were less competitive with the locust seedlings than were cool-season species.

**U.S.-KY : coal-B : VI-B**

555. Wagner, Aubrey J.
1965. **Aubrey J. Wagner speaking on Tennessee Valley Authority.** Ky. Dep. Nat. Resour. Strip Mine Reclam. Symp. Proc.: 23-27. Frankfort.

A summary of TVA experiences with strip-mining for coal and other commodities, and land reclamation.

**U.S.-TN : coal-B, other : VI**

556. Waldbieser, William C.
1968. **Development of equipment for cast overburden reclamation.** Min. Congr. J. 54 (7) : 50-51.

Equipment and methods for the reclamation of strip-mine spoils are reviewed. Larger trenchers, use of booster draglines, and wheel excavators are discussed.

**U.S. : coal : II-A**

557. Wali, Mohan K., ed.
1973. **Some environmental aspects of strip mining in North Dakota.** N.D. Geol. Surv. Educ. Ser. 5. 121 p.

A product of a symposium held by the North Dakota Academy of Science, containing eight papers dealing with the environmental impact of strip-mining and the viewpoints of individuals in various fields of specialization.

**U.S.-ND : coal-L : VIII-D**

558. Wali, M. K., and P. G. Freeman.
1973. **Ecology of some mined areas in North Dakota.** *In* Some environmental aspects of strip mining in North Dakota. N.D. Geol. Surv. Educ. Ser. 5: 25-47.

Plant species diversity and an abundance of physical and chemical characteristics of mined and unmined sites were studied. Species diversity was higher at unmined sites. Mined sites showed sparser vegetation with reduced growth and vigor. Mined sites showed higher pH and conductivity, replaceable Mg, Na, total P, and S. The unmined sites were

higher in organic matter, replaceable K, and EDTA-extractable Mn. High Mg levels may be an additional problem.

**U.S.-ND : coal-L : III+VI-B**

559. Walp, Neil M., and Robert M. Gidez.
1965. **Commerce and planning and their relationship to mining.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 24-27. University Park.

States, areas, and communities have suffered greatly from poor mine area planning. We must plan to eliminate the landscape scars and meet the future head-on with effective regulations to ensure the rehabilitation of strip-mined lands that will foster commercial development. Some criteria required by the planner to evalute strip-mine spoils for economic development are discussed.

**U.S. : coal : VIII-A**

560. Warner, Richard W.
1973. **Acid coal mine drainage effects on aquatic life.** *In* Ecology and Reclamation of Devastated Land vol. 1: 227-237. Gordon and Breach Sci. Publ., New York.

Reaches of Roaring Creek, West Virginia, that were severely polluted by acid drainage (pH 2.8 to 3.8) were inhabited by low diversities of 3 to 12 taxa of benthic invertebrates and 10 to 19 species of algae. Stream reaches with pH values of 4.5 and higher supported communities of 25 or more invertebrates and 33 or more species of attached algae. High concentrations of acidity, total and ferrous iron, sulfate, hardness, calcium, and aluminum produced a complex and varying aquatic environment.

**U.S.-WV : coal-B : IV-G**

561. Watson, A. E. P.
1969. **Pollution problems associated with base metal mines.** Can. Min. J. 90 (6): 50-54.

A progress report on water-pollution problems associated with base metal mines. Data on pH, conductivity, hardness, Cu, Zn, Fe, and sulfate concentrations in the effluent from tailing ponds sampled daily, and from continuously recording field monitor instruments, are discussed.

**Canada-NB : ore waste : V-B**

562. Watson, W. Y., and D. H. Richardson.
1972. **Appreciating the potential of a devastated land.** For. Chron. 48 (6): 312-315.

Discussion on the dimension of land and vegetation devastation due to nickel smelting, giving examples of reclamation and suggestions about how implementation of an overall land-use policy might enhance the esthetic value of the damaged area.

**Canada-ON : ore waste : VI-B**

563. Weigle, Weldon K.
1965. **Designing coal-haul roads for good drainage.** USDA For. Serv. Cent. States For. Exp. Stn. 23 p., illus. Columbus, Ohio.

A guide to help in planning, locating, constructing, and maintaining coal-haul roads on small coal company lands, with special emphasis on drainage.

**U.S.-KY : coal-B : II-D+VI-A**

564. Weigle, Weldon K.
1965. **Road erosion and spoil-bank stability.** Pa. State Univ. Mine Spoil Reclam. Symp. Proc.: 82-85. University Park.

A discussion of erosion on abandoned haul roads and spoil-bank outslope instability observed on contour-type strip mines in eastern Kentucky. Mining and road-building practices on strip mines are mentioned; problems with erosion and instability are outlined, and some practical solutions to these problems are suggested.

**U.S.-KY : coal-B : IV-E**

565. Weigle, Weldon K.
1966. **Erosion from abandoned coal-haul roads.** J. Soil and Water Conserv. 21 (3): 42.

Five and 2.6 inches of road surface of clayey silt and sandy silt soil respectively were lost

per year due to erosion of abandoned coal-haul roads.

**U.S.-KY : coal-B : II-D+IV-E**

566. Weigle, Weldon K.
1966. **Spoil bank stability in eastern Kentucky.** Min. Congr. J. 52, (4) : 67-73.
The stability of certain spoil-bank slopes was studied, and the respective safety factors were computed. The widths of stable fill-benches depend on percent of original mountain slope.

**U.S.-KY : coal-B : VI-A**

567. Weigle, Weldon K., and George P. Williams.
1968. **Match additive to soil types for best stabilization.** Rural and Urban Roads June 1968: 24-25.
This article highlights a basic stabilization problem — matching soils to the stabilizing agent. Some soils need different stabilizing treatment than others.

**U.S.-KY : coal-B : VI-A**

568. Wells, J. Ralph.
1953. **The reclamation of stripmined ears in southeastern Kansas.** Kans. Acad. Sci. Trans. 56 (3) : 269-292, illus.
Spoilbanks are favorable for the growth of a variety of plants, both volunteer and planted; leveling is not necessary; allowing spoilbanks to stand for several years is not required for successful seeding and planting; the use of orchards and vineyards offers little success in reclaiming striplands; forest tree plantings are too uncertain to be recommended; conversion to pasture is believed to be the most practical means of reclaiming large acreages of spoil banks; the spoils provide habitats for fish and wildlife, and they are being developed.

**U.S.-KS : coal-B : VI+VII**

569. Welsh, George W., and R. J. Hutnik.
1973. **Growth of tree seedlings and use of amendments on bituminous refuse.** Pa. State Univ. Sch. For. Res. Briefs 7 (1) : 34-37.
Under greenhouse conditions even highly toxic breaker refuse can support plant growth if properly amended. On banks of moderate toxicity, fertilization alone might result in increased growth; otherwise the toxicity has to be minimized before a response to fertilization can be obtained.

**U.S.-PA : coal-B+R : III-B+VI-B**

570. Wheeler, Wilson H.
1962. **Reclamation of strip mined land in Pennsylvania.** Pa. Dep. Health Nat'l. Symp. on Control of Coal Mine Drain. Proc. Publ. (4) : 71-73.
A discussion of strip-mine reclamation in the bituminous coal fields of Pennsylvania in relation to the state's laws and regulations.

**U.S.-PA : coal-B : VIII-A**

571. Wheeler, Wilson H.
1965. **Progress in reclamation with forest trees.** Pa. State Univ. Coal Mine Spoil Reclam. Symp. Proc.: 111-116. University Park.
A review on performance of forest tree plantations on bituminous coal-mine spoil in Pennsylvania from the point of view of a forester-practitioner. Observations on tree species, planting material, and season, as related to certain spoil characteristics.

**U.S.-PA : coal-B : VI-B**

572. Williams, E. G., and M. L. Keith.
1963. **Relationship between sulfur in coals and the occurrence of marine roof beds.** Econ. Geol. 58: 720-29.
The hypothesis that regional variation of sulfur in coal beds is related to the influence of penecontemporaneous marine water is tested by stratigraphic and statistical methods. The Lower Kittanning coal exhibits regional variations in sulfur content which are statistically related to the regional changes in overburden, areas of marine overburden being higher in sulfur than continental areas. The Upper Freeport coal, overlain entirely by continental beds, shows no regional sulfur variation. The authors conclude that the presence or absence of mar-

ine waters was one of the factors controlling regional variation of sulfur in coal.

**U.S.-PA : coal-B : III-B**

573. Williams, George P.
1967. **Roads, slides and check dams.** Ky. Dep. Nat. Resour. Strip Mining Symp. 4 p. Frankfort.

A brief and general discussion of aspects of civil engineering applicable to problems in watershed protection on strip-mined areas. Roads, spoil-bank mass stability, and runoff and erosion control are touched upon.

**U.S.-KY : coal-B : VI-A**

574. Williams, George P., Jr.
1973. **Changed spoil dump shape increases stability on contour strip mines.** Res. and Appl. Tech. Symp. on Mined Land Reclam. Proc.: 243-249. Bitum. Coal Res., Inc., Monroeville, Pa.

A 1967 survey of strip mines operating under 1966 regulations in eastern Kentucky showed that 94 percent of the outslopes were stable. Of 178 slides that occurred, 50 percent involved spoils dumped in valleys. Slide incidence and terrain steepness were not found to be related. Changes in spoil distribution and spoil dump shape accounted for a 42 percent reduction in disturbance by spoil slides and a 17 percent reduction in total area disturbance.

**U.S.-KY : coal-B : VI-A**

575. Williams, Roger L.
1971. **Reclamation! How much and when.** Rehabil. Drastically Disturbed Surf. Mined Lands Symp. Proc.: 2-10. Surface Mined Land Use Board. Macon.

The keynote address to the first symposium. A general discussion of all kinds of pollution problems prevalent in the United States today. It includes some statistics and a historical summary of reclamation legislation.

**U.S. : coal, other : VIII-A**

576. Wilson, H. A.
1951. **Strip mine spoils — they can be reclaimed.** W. Va. Univ. Agric. Exp. Stn. Bull. 349 (1) : 8-9 p., illus. Morgantown.

Beneficial microorganisms, vegetation, and proper soil management are helpful in building up the fertility of spoils.

**U.S.-WV : coal-B : III-D**

577. Wilson, H. A.
1957. **Effect of vegetation upon aggregation in strip mine spoils.** Soil Sci. Soc. Am. Proc. 21 : 637-640.

Aggregation in the coal mine spoils was in the following order: non-vegetated<vegetated<undisturbed. The forested iron-ore spoils are not as well aggregated as the adjacent soils. The type of vegetation is an important factor. Aggregation increased in the following order: non-vegetated<pine<locust<forage grasses and legumes.

**U.S.-WV : coal-B : III-C+VI-B**

578. Wilson, H. A.
1961. **Rhizosphere bacteria of some strip-mine vegetation.** W. Va. Acad. Sci. Proc. 33 : 15-20.

Bacteria were isolated from roots, root washings, and the rhizosphere of legumes growing on spoil, and from barren spoil. Medium-size gram-negative rods predominated among the isolates, and most of the isolates required the unidentified substances of yeast extract for maximum growth. Root isolates exhibited more ability to produce a polysaccharide from glucose than the isolates from any other source. The isolates from nonvegetated spoil had the least polysaccharide-producing ability.

**U.S.-WV : coal-B : III-D**

579. Wilson, H. A.
1965. **The microbiology of strip-mine spoil.** W. Va. Univ. Agric. Exp. Stn. Bull. 506T. 44 p., illus. Morgantown.

Samples from several spoil areas were studied to determine the number of bacteria, fungi, and actinomycetes present. The chemical activities of the spoil microorganisms were documented in related studies.

**U.S.-WV : coal-B : III-D**

580. Wilson, H. A., and H. G. Hedrick.
1957. **Carbon dioxide evolution from some strip mine spoils.** Appl. Microbiol. 5 (1) : 17-21.

Production of $CO_2$ by microbial populations of nonvegetated and vegetated strip-mine spoils was studied. The addition of N to the spoil, alone or in combination with other elements, had more influence upon the microbial activity than other additions. The addition of $Ca(HO)_2$ was influential in increasing microbial activity, particularly in samples that received an addition of organic matter.

**U.S.-WV : coal-B : III-D**

581. Wilson, H. A., and H. G. Hedrick.
1957-58. **Some qualitative observations of the microflora in a strip mine spoil.** W. Va. Acad. Sci. Proc. 1959: 35-38, illus.

Bacteria, fungi, and actinomycetes grow and multiplied in strongly acid nonvegetated and vegetated spoils, both with and without the addition of organic matter. The addition of organic matter increased the number and kinds of microorganism and favored closer growth of the microorganisms.

**U.S.-WV : coal-B : IV-D**

582. Wilson, H. A., and H. G. Hedrick.
1959-1960. **Extractable sulfates and iron in strip mine spoil acid spots.** W. Va. Acad. Sci. Proc. 31-32: 21.

Acid spots on strip-mine spoils snow considerably more soluble sulfates than areas devoid of acid spots.

**U.S.-WV : coal-B : III-B**

583. Wilson, H. A., and Gwendolyn Stewart.
1955. **Ammonification and nitrification in a strip mine spoil.** W. Va. Univ. Agric. Exp. Stn. Bull. 379T. 16 p., illus. Morgantown.

The study documented the transformation of organic nitrogen to ammonium nitrogen from different materials incorporated into nonvegetated, vegetated, and undisturbed acidic spoils. It also showed that strongly acid spoils must be limed before nitrification takes place.

**U.S.-WV : coal-B : III**

584. Wiltsee, Herbert L.
1965. **A proposed interstate mining compact.** Ky. Dep. Nat. Resour. Strip Mine Reclam. Symp. Proc.: 31-35. Frankfort.

Presents the provisions of the draft of the proposed "Interstate Mining Compact" initiated by many state governments, and the reasoning behind them.

**U.S.-KY : coal-B : VIII-A**

585. Wood, R. F., and J. V. Thirgood.
1955. **Tree planting on colliery spoil heaps.** For. Comm. Res. Branch Pap. 17. 18 p. Forestry Commission, London.

Most of the spoil heaps are potentially fertile, can supply sufficient moisture, and thus are capable of supporting tree growth. High slopes, erodibility, heap fires, and vandalism present difficulties in revegetation.

**England : coal : VII-D**

586. Wood, R. F., and J. V. Thirgood.
1955-56. **Tree planting on colliery spoil heaps.** Colliery Eng. 32: 512-516 and 33: 27-32. London.

The authors discuss the possibilities and difficulties of tree planting on spoil heaps. In the first portion of the article, the authors give information about general environment, physical and chemical characteristics, and special features of burned heaps. In the second portion, the authors present the records of tree growth and discuss site preparation and plantation performance.

**England : coal : III+VI-B**

587. Young, C. A.
1969. **The use of vegetation to stabilize mine tailings areas at Copper Cliff.** Can. Min. J. 90 (6) : 43-46.

The methods used to stabilize and secure vegetative cover on very acid mine tailings are described. Site preparation, seeding, and

fertilization are discussed. Grass cover has been established on more than 500 acres.

**Canada-ON : ore waste : VI-B**

588. Younge, O. R., and J. C. Moomaw.
1960. **Revegetation of stripmined bauxite lands in Hawaii.** Econ. Bot. 14 (4) : 316-330 p., illus.

The authors discuss the occurrence, conditions for formation, and commercial potentials of the bauxites, describing vegetation associations of bauxitic areas and reviewing land-use history. Site preparation and revegetation of strip-mined lands, and the beneficial yield effects obtained from lime, N-P-K fertilizer, and mulches are also discussed.

**U.S.-HI : bauxite : VI**

589. Zande, Richard D.
1973. **Friendship park — one use of reclaimed strip-mine land.** Res. and Appl. Tech. Symp. on Mined-Land Reclam. Proc.: 294-303. Bitum. Coal Res., Inc., Monroeville, Pa.

The plans to turn 1,100 acres of strip-mined land in Jefferson County, Ohio, into park lands are reviewed. The land was donated to the county by Hanna Coal Co., Cadiz, Ohio, a division of Consolidation Coal Co. An 85-acre lake for fishing and boating is being formed by construction of an earth-fill dam. An airport, picnic areas with shelters, and hiking trails are also included in the nearly completed phase I of the project.

**U.S.-OH : coal-B : VII-A**

590. Zarger, T. G., G. W. Bengtson, J. C. Allen, and D. A. Mays.
1973. **Use of fertilizers to speed pine establishment on reclaimed coal-mine spoil in Northeastern Alabama.** II. Field experiments. *In* Ecology and Reclamation of Devastated Land vol. 2: 227-236. Gordon and Breach Sci. Publ., New York.

N and P are the main elements limiting growth of loblolly pine on coal mine spoils in Alabama. Early results showed a significant increase in seedling height when P was added at 100 pounds per acre. Additional growth and improvement in color and vigor resulted when N was applied with P at rates of 25 to 100 pounds. Seeded pines also responded to NP fertilizer applied at rates 100 pounds per acre of each element. Few seedlings were killed by frost heaving when the spoil was fertilized.

**U.S.-AL : coal-B : VI-B**

591. Zarger, T. G., J. A. Curry, and J. C. Allen.
1973. **Seeding of pine on coal spoil banks in the Tennessee Valley.** *In* Ecology and Reclamation of Devastated Land vol. 1: 509-523. Gordon and Breach Sci. Publ., New York.

Tree seeding tests were established on graded and ungraded spoils to evaluate time, rates, and treatments. Loblolly, shortleaf, Virginia and white pine were tested. Two-year results show that the March to mid-April seedlings gave satisfactory seedling stands. Stratified and repellant-treated loblolly pine seeded at 1.0 and 1.5 pounds per acre or Virginia pine at 1.0 pound per acre produced stands of 1,500 seedlings. White pine stratified for 60 days and seeded at 1.5 pounds produced 1,300 seedlings. Shortleaf pine produced poorer results.

**U.S.-AL, TN, VA : coal-B : VI-B**

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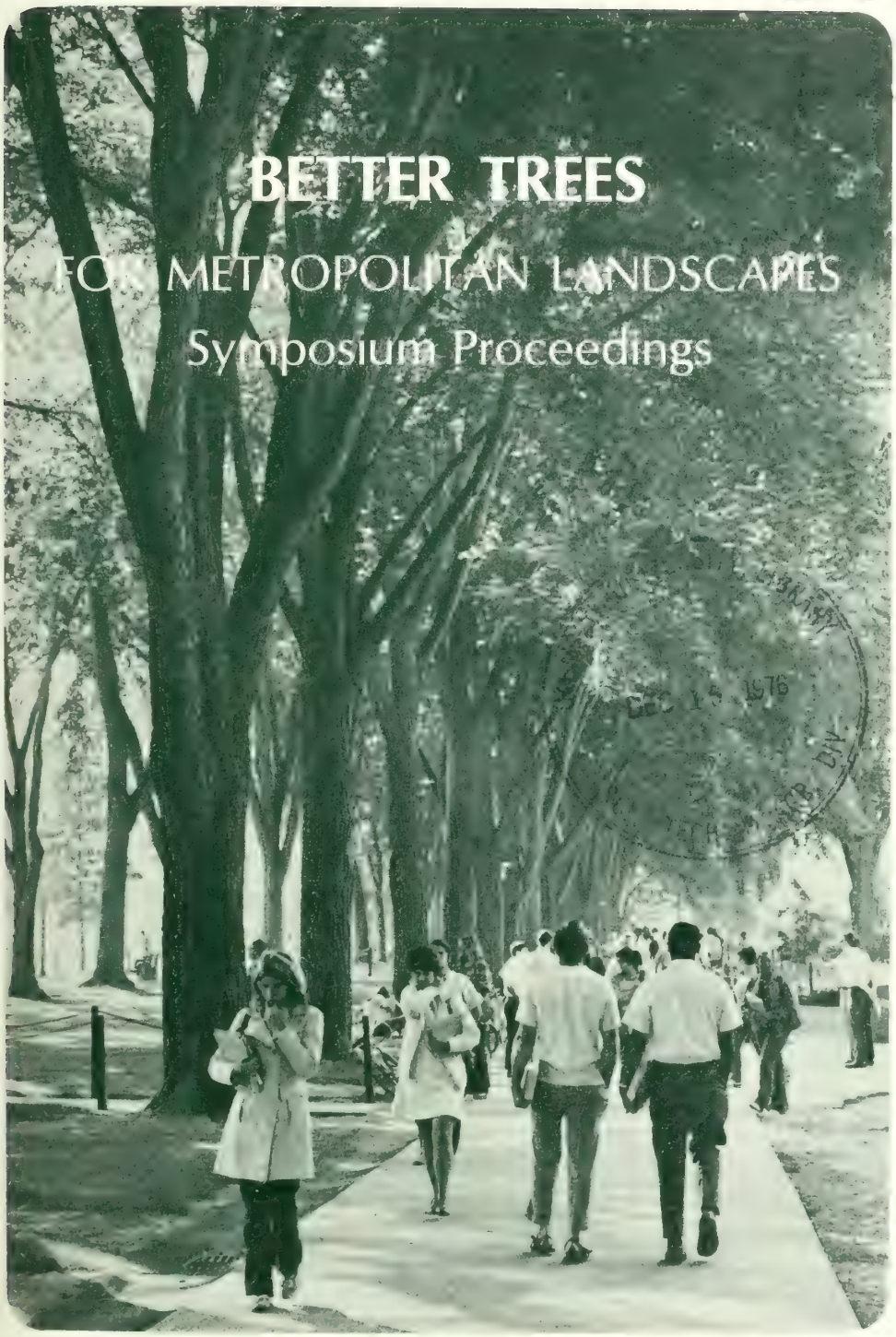
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# BETTER TREES
## FOR METROPOLITAN LANDSCAPES
### Symposium Proceedings

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# BETTER TREES

## FOR METROPOLITAN LANDSCAPES

**Edited by**

**Frank S. Santamour, Jr.**
**Henry D. Gerhold**
**Silas Little**

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**Proceedings of the Symposium held on 4-6 November 1975, at the U.S. National Arboretum, Washington, D.C.**

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—**FRANK S. SANTAMOUR, JR.**
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**SILAS LITTLE**
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# FOREWORD

THE MORE MAN physically alienates himself from the natural world, the more he seems to try to retain some of the amenity values associated with the natural environment. He goes to great expense to retain these values. Urban residents steadfastly support street-tree and forest-management programs. Tree planting and maintenance of urban vegetation systems have become a multimillion dollar industry. Yet little effort has been exerted to develop trees that are adequately suited to the unique conditions found in metropolitan environments.

Where urban forest vegetation exists—whether in parks, greenbelts around cities, along streets, or in scattered forest tracts—it modifies and improves the living environment. Urban forest vegetation provides sites for recreation, protects and maintains water supplies, filters waste water, enhances property values, provides habitat and sanctuary for wildlife, enhances the visual landscape, abates noise, cleanses the atmosphere, and ameliorates climate.

The metropolitan environment is an extremely hostile place for trees. Nature has produced few tree species that are adapted to urban conditions. Most cultivars now used in urban areas are selected for their unique appearance, not for their ability to survive hostile urban conditions. This practice has contributed greatly to high costs of urban tree maintenance and tree mortality. It is essential that trees be developed that are biologically and functionally adapted to metropolitan conditions as well as esthetically pleasing.

The Pinchot Institute for Environmental Forestry Research was established to develop the knowledge needed to solve problems of policy formulation, land planning, and forest and open-space land management in and around metropolitan areas. It conducts an interdisciplinary research program designed to improve urban living conditions through manipulation of urban vegetation systems. The Pinchot program is a coordinated effort between the U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, and the Consortium for Environmental Forestry Studies, which is an organization of nine northeastern Universities and the Forest Service. The Consortium's Working Group on Genetics of Urban Trees is one of eight technical groups through which Consortium research is organized. The Genetics Group is concerned with development and dissemination of genetic information on urban forest vegetation, including selection, breeding, propagation, and production of genetically superior urban trees.

The purpose of this symposium was to provide up-to-date information about tree selection, cultural practices, evaluation and testing techniques, and tree-breeding methods for trees to be used in urban environments. We hope that this report on the Symposium will help to improve communication and coordination among researchers, urban planners, arborists, foresters, tree breeders, and commercial nurserymen.

The Symposium sessions were attended by more than 200 participants from 24 States, Canada, Holland, and Sweden. A broad array of professional and technical people were represented, including researchers, arborists, foresters, landscape specialists, nurserymen, urban planners, and extension specialists.

Financial support was provided by the Pinchot Institute for Environmental Forestry Research, Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture. Facilities and meeting arrangements were

coordinated by the National Arboretum, Agricultural Research Service, U.S. Department of Agriculture. In cooperation with the Experiment Station and the National Arboretum, the School of Forest Resources of the College of Agriculture, the Pennsylvania State University, conducted the program as a continuing education service.

**—GEORGE H. MOELLER**
*Program Coordinator,*
*The Pinchot Institute*

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## Program Advisory Committee

The Symposium, BETTER TREES FOR METROPOLITAN LANDSCAPES, was organized through the Metropolitan Tree Improvement Alliance and conducted as one of the activities of the Working Group on Genetics of Urban Trees of the Pinchot Institute Consortium for Environmental Forestry Studies. Members of the advisory committee were:

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# BREEDING AND SELECTING BETTER TREES FOR METROPOLITAN LANDSCAPES

*by* FRANK S. SANTAMOUR, JR., *Research Geneticist, U.S. National Arboretum, Washington, D.C.*

*ABSTRACT.* The development of superior trees for planting in metropolitan areas is in its infancy. Although many of the techniques and methods of plant breeding for other crops can be adapted to this endeavor, there are certain special features that influence the successful production of better trees for people. Some of the problems and prospects of developing better trees are discussed—with emphasis on diversity within and among species, the consequences of clonal uniformity, adaptability (to climatic conditions, pests, stresses, and successful nursery culture), "personality", and reliability of plant materials.

THE DEVELOPMENT OF SUPERIOR shade and landscape trees for metropolitan areas represents a challenge that is not matched by any other type of plant breeding. Crop geneticists and petunia breeders work with plants that have a short generation time and in which the cultural factors are normally kept near optimum. Forest geneticists may deal with long-lived trees, which are normally grown under near-natural growing conditions, and little effort is expended in their culture.

However, forestry planting and rotations are such that only 20 percent of the trees initially planted may suffice for a successful final harvest. In contrast, the urban tree has a high unit cost and value, both at the time of planting and, increasingly, year after year. Thus, 100 percent survival is *expected* under the prevailing adverse conditions. Better metropolitan trees must also be amenable to the production practices of commercial nurseries and must be subjected to long-term testing. Furthermore, the selected trees are frequently planted in environments alien to tree growth, where cultural care after planting may be minimal.

Research to develop superior trees for use in populated areas is in its infancy. Even at this stage, there are problems in terminology. The trees are described as "shade", "amenity", "ornamental", "street", "landscape", or "environmental"; and their use is intended for "urban", "metropolitan", or "megalopolitan" areas. Basically we should be working on "trees for people".

In discussing in a general way, some of the problems and prospects in the development of superior "trees for people", there is no royal road to follow and few, if any, absolutes as guideposts. However,

if we understand and appreciate the tree qualities that must be considered, better trees are sure to follow.

## DIVERSITY

It is perhaps significant that the current surge of scientific interest in developing superior metropolitan trees coincides with a low point in the diversity of tree materials being grown by the nurserymen. Economic, biological, and ecological factors are forcing nurserymen to stop growing species or cultivars that have limited sales potential, that have proved marginally adaptable to urban situations, or that require liberal applications of pesticides to insure their well-being.

In addition to these factors, many of the old-timers or plantsmen, whose love of plants was reflected in the breadth of their nursery listings, are passing out of the picture. More and more, nurseries are assuming a corporate structure; and the plants, like loaves of bread, are merely the produce of the venture. Of course, it makes good economic sense to produce a limited number of high-quality products. The tree geneticist can be a driving force in the quest for quality trees. But there are other considerations.

What we need, desperately, is increased diversity. The metropolitan environment provides a unique blend of sites and settings for the utilization of the widest possible range of tree and shrub materials. We have more than enough genera and species to provide the range of form, color, and texture necessary for optimum development of any metropolitan area. The landscape architect must be provided with the raw materials to do his job.

Look at the collections of trees in our major arboreta or botanic gardens. Why are so few of these species currently in the commercial nursery trade? The problems are economic, biological, and ecological. But they are not insurmountable. In fact, there are many cases where an improvement in a single, simple characteristic might change the status of an otherwise undesirable tree.

With more than 100 genera and hundreds of species capable of successful culture in temperate United States, it will be the scientists' job to survey this array of plant material and determine what type of selection and breeding program could produce desirable and useful trees.

One of the benefits of increased diversity of genera and species is that the nurseryman and the tree grower are insured against major losses that might be caused by new pest outbreaks, climatic disturbances, or man-made changes in the environment. The chances of having the right tree in the right place are increased immeasurably. Other benefits accrue to the tree user who looks at, drives by, stands under, or listens to the trees as an integral part of his world.

Another aspect of diversity is genetic diversity *within* a species. As we continue to seek and promote the reliability and uniformity of clones and cultivars, this diversity is being diminished. Seedling populations of trees provide us with thousands of different genotypes, but some nurseries may now offer only seven genotypes (cultivars), or three, or one. It is a common argument that the maintenance of genetic diversity *within* a species is a safeguard against possible disaster when new pests or new pest strains become abundant. Certainly the entire range of genetic diversity within *Castanea dentata* did not save the American chestnut from chestnut blight. The American elm-Dutch elm disease situation offers only slightly more promise. Intraspecific genetic diversity must be maintained in breeding programs and gene banks, but to try to maintain all of this diversity on the city streets would defeat the purpose of breeding and selecting superior genotypes.

## UNIFORMITY

There is no doubt that the current trend of selecting and using cultivars will will continue in the nursery trade. It makes good sense. When a genotype has been proved superior in pest resistance, stress tolerance, and general adaptability,

it would be unwise not to exploit this superiority. Each cultivar becomes a standard of performance and reliability. The municipal arborist, the landscape architect, and the homeowner will choose a particular cultivar because of its uniformity in desirable characteristics.

Cultivars or clones may also be uniform in undesirable traits. Even after long-term testing, hidden flaws may become apparent under new conditions. What degree of diversity we need and should strive for will certainly be one of the key arguments among scientists.

As generally conceived, cultivars are clones. That is, they represent identical genotypes that are reproduced vegetatively. Plants grown from cuttings certainly fit this concept. However—and the point may be academic—how can we consider, as a clone, the plants that are reproduced by budding or grafting on rootstocks of seedling origin? Is the root system of such little importance in the life of the tree that we can ignore this source of variation? Generally, of course, the influence of *average* rootstocks on the above-ground characteristics of a grafted tree are not sufficient to dramatically alter the phenotype. But there are nematodes, salty and compacted soils, and soil-borne pathogens that may play an important role in the tree's survival.

Thus, there is also a need for the selection and propagation of superior and uniform rootstocks. The degree of uniformity needed might not be clonal, but only enough to insure the tolerance or resistance levels for optimum survival. For instance, it might be that seedlings of a particular elm *species* could serve as Verticillium-resistant rootstocks for the grafting of superior and disease-resistant scions. Still, few nurserymen or scientists would care to take potluck on the source of the seedling rootstock. Again, a certain degree of uniformity and reliability is desirable and necessary.

We might also desire uniformity in graft compatibility, but our inadequate knowledge of the factors influencing the stock-scion relationship make this desire more of a wish. We have been rather lucky, I think, that few cases of latent graft failure have caused problems in the nursery or on the street. The skill and experience of the nurseryman has been the key to success in this area, and until some scientific data are available, the situation will remain the same.

### Seedling Cultivars

A cultivar, according to the Code (*International Code of Nomenclature of Cultivated Plants*, 1969), does not have to be a clone, nor must it be vegetatively propagated. The only requirements are ". . . an assemblage of cultivated plants which is clearly distinguished by any characters (morphological, physiological, cytological, chemical, or others), and which when reproduced (sexually or asexually), retains its distinguishing characters" (Article 10).

Vegetative propagation by cutting, grafting, or budding requires special facilities and skill, time, and money. There are also certain important genera or species (oaks, some maples) that cannot be economically reproduced by cuttings or grafting.

Quite possibly the ultimate achievement in shade-tree improvement will come when we can grow superior trees from seed. The way is open for the use of controlled crosses and seed orchards in the production of superior cultivars. Both intra- and interspecific combinations are possible. It might also be possible to utilize natural or induced apomixis (asexual seed production) for the rapid increase of desirable genotypes. Seedling cultivars can provide the needed uniformity in survival characteristics (and, we hope, in growth characters), while allowing a modest degree of intra-cultivar genetic diversity.

## ADAPTABILITY

Progress in metropolitan tree improvement will proceed by a series of successive approximations to certain ideals, but

the conditions that influence the tree's performance are highly variable in time and space. Here are some topics that must be taken into account if a new cultivar is to be widely accepted.

### Provenance

Climatic adaptability is obviously an important characteristic, and winter- or cold-hardiness is the most frequently cited criterion. Data given in most tree lists on the northernmost "Hardiness Zone" are based on *species* performance. A nurseryman growing red maple seedlings of local origin in Tennessee may advertise his product as being hardy to Zone 3 (say, St. Paul, Minnesota). While it is true that *Acer rubrum* has a native range encompassing Zone 3, and even parts of Zone 2, there is no guarantee, and little likelihood, that the Tennessee maples will be completely adapted to the colder climates.

One of the most neglected aspects of tree adaptability in the nursery trade is the matter of provenance, or geographic origin of the genetic material. Our native tree species frequently occupy a wide latitudinal and elevational range. Particular populations grow where they do because they are acclimated to the natural environment. Movement of this germ plasm too far north, or south, may result in less than optimum growth and survival.

For non-native species, there is frequently much less information available. We may know the native *range* of the species but not the precise locality of origin of our seed or of a tree in an arboretum. Judgments as to potential hardiness are sometimes based on the coldest zone in which a tree of a particular species exists. Many mistakes have been made by using this criterion of hardiness.

Without belaboring the point further, let me say that the provenance of a tree may well determine its utility. As the selling range of nurseries is increased, and coast-to-coast (in North America) is not unusual, cultivars of unknown origin may be spread throughout the country. Application of adequate long-term testing results could help avoid some of the bad consequences of this practice.

Before leaving this topic, I should point out that provenance is important not only to hardiness. The movement of plant materials far south of their native or adapted range may cause less dramatic problems, but they are real ones. The long hot summers and drought are only two of the many environmental survival factors that must be considered. In addition, flowering, fruiting, and autumnal leaf coloration may be altered significantly.

For the future, the scientist must be aware of provenance in the selection of parent material and in his choice of test sites. Furthermore, he should endeavor to spread this concern for provenance to nurserymen, arborists, and the public.

### Pest Resistance

If a neophyte researcher were to consult the various references listing the diseases and insect pests of shade trees, he might consider it just short of miraculous that there are any elms or poplars that have survived the biological blitz. On the other hand, he would note that relatively few pests appear to plague certain tree species that are relatively rare in cultivation. It is axiomatic that the number of pests associated with a crop increases with more extensive culture—and intensive observation. There are major pests, minor pests, and unknown pests. What pests are important and how much resistance do we need?

In some genera, the ranking of priorities may be relatively easy. For elms, resistance to Dutch elm disease, phloem necrosis, and Verticillium wilt are in a reasonable order. Among elm insects, the elm leaf beetle would probably be considered the most destructive. Surely, if cultivars were developed with resistance to all the above pests, and possessed reasonable growth habits, they could find ready acceptance in the nursery trade. Nectria canker might still be a problem,

and leaf spots, and wetwood, and borers, and cankerworms, and aphids. Where do we stop?

The elms, as noted above, are a special case. Consultation of standard references will show a large number of genera and species with only a few serious pests, or none at all. Wouldn't it make good sense to work with these genera and species?

Maximum improvement of our metropolitan environments will come when we seek to improve *all* genera and species that are available to us. The need for diversity is urgent and important.

Pests that are *limiting* factors in the successful culture of a tree are the obvious first choices for resistance breeding and selection. Inoculation with the most virulent or aggressive strains of the pathogen or long-term exposure to natural, or enhanced, insect populations will be necessary to achieve significant improvement. All tree geneticists, pathologists, and entomologists realize the problems; but each may have strong personal opinions on the relative importance of certain pests and the degree of resistance required. There are no *absolute* answers to these questions.

The diversity of opinions and approaches, of genes and selective factors, of techniques and criteria, plus intensive and extensive testing, should provide pest-resistant trees for tomorrow.

### Stress Tolerance

There is no doubt that certain man-made stresses imposed on trees in metropolitan environments are major factors in tree growth and survival. Any reduction below optimum growing conditions may make the tree more susceptible to insect, disease, and nematode pests that might otherwise not be problems.

We are fortunate that we can duplicate —under laboratory or controlled field conditions—most of these stress situations. Tolerance of salty and compacted soil is amenable to field and greenhouse experimentation. The effects of gaseous air pollutants may be tested in special chambers. The response of trees to certain sources of artificial illumination can be determined. Furthermore, the response of trees to injuries caused by automobiles and other mechanical agents can be assessed by observing healing patterns of pruning cuts or deliberate trunk wounds during the testing period.

Screening procedures against stress factors may be applied to populations or individual selections and at different stages in the improvement program. For instance, tests of salt tolerance were conducted on seedlings of progenies resulting from crossing *Platanus occidentalis* and *P. orientalis* at the National Arboretum. Individuals exhibiting resistance to sycamore anthracnose disease in field tests were selected from those progenies that had demonstrated the highest salt tolerance. After further observations on anthracnose, selected clones may then be subjected to salt testing once more before final selections are made. Or the clones may be screened for ozone or sulfur dioxide tolerance.

Stress conditions are seldom the limiting factors to the successful culture of a tree. The limiting factor in *Platanus* is anthracnose. The only reason salt-tolerance testing preceded other tests was that we had an abundance of seed, more than we could possibly use in producting trees for long-term field tests.

Where the number of seed or seedlings is small, stress-tolerance testing should be postponed until after resistance to major pests has been determined. If there are no major pests, the entire improvement program may consist of stress testing.

While we can work with stress factors singly, the trees on the streets are subjected to these conditions in combination with each other, and with biological and climatic factors. We cannot hope to duplicate, or even account for, all of the variable conditions. Thus, the best products of our laboratory and field studies must be tested on the street. The more ruthless we are in our screening and se-

lection procedures, the better the chances are for the survival and use of our improved trees.

### Nursery Practices

The builder of the better mousetrap may have had a well-worn path beaten to his door, but the builder of a better chestnut *(Castanea)* tree has not been so fortunate. The new blight-resistant chestnut hybrids developed by the Connecticut Agricultural Experiment Station have not aroused much interest in the nursery industry. There may be several reasons for this apathy, but certainly one of the major deterrents to widespread acceptance of these chestnuts has been the lack of successful mass-propagation techniques. Obviously, propagation of these hybrids by seed is nearly impossible. Chestnuts do not root well from cuttings, and grafting is only slightly more effective. So the superior genotypes, developed after more than 40 years of breeding and testing, stand as reminders that good intentions and success in breeding are not enough.

The oaks are also difficult to propagate. Little breeding effort has been expended on this genus, and the few selected species cultivars may be exhibiting signs of latent graft incompatibility.

The cheapest and most efficient method of tree production is by seed. If an improved seed-propagated cultivar can be increased by seed giving reliable and uniform germination, there would be little doubt about its wide acceptance and use. We should remember, however, that such a cultivar should also be uniform in desirable traits relating to survival and growth. Tree species that are heavy and consistent seed producers will be best adapted to this method of propagation.

The next most effective and least costly method of propagation is the rooting of cuttings. The development of rooting hormones and mist systems now allow cutting propagation of many species and genera that were difficult or impossible to root in the past. Still, there are many species in which rooting success is economically marginal, and much remains to be learned. The geneticist must be the experimental propagator of such material. Juvenility may be the key to success in many species, and initial propagation soon after the first selection cycle may be important. Further propagations may be made from sprouts after the propagations have been cut back. Perhaps there are not many nurseries that maintain stock blocks that are handled on a cut-and-sprout basis; but if the scientist can demonstrate that *some* method of rooting is successful, the chances of his material being mass-produced are increased.

There is also another advantage to the scientist-as-propagator scheme. When plants are sent to nurserymen or others for evaluation, all parties are sure that the genotype is pure—from root tip to apical meristem. Thus, the possibilities of cultivar contamination by rootstock sprouts are eliminated and more accurate appraisals of the tree's value are assured.

There are, perhaps, not many scientists who are skilled in budding or grafting, or who have a skilled person available to do it for them. If the superior selections are of sufficient interest or potential, it is possible that a nurseryman would be willing to assist in tests of propagation.

Some trees require extensive "training" in the nursery in order to develop the kind of trunk and crown that makes a salable tree. The increase of container-growing in nurseries may impose other restrictions on the characteristics desired for mass production. The ease of transplanting, although not necessarily the province of the nurseryman, will certainly be a factor in decisions on what the nursery produces.

There are few, if any, trees that cannot be propagated and planted successfully if enough time, money, and effort are expended. However, if the nurseryman and the scientist are to get the greatest number of the best possible trees to the largest number of people in the shortest

possible time, serious attention must be given to the biology and economics of mass production.

## PERSONALITY

We have thus far been considering the traits necessary for survival and utility. A living, green tree is a thing of beauty. But man is a seeker of novelty and variety and the cosmetic industry is a prosperous one.

Most of the cultivars presently in the nursery trade were chosen for their personality, the traits that differentiate them from the norm. Weeping, fastigiate, columnar, globe, and vase-shaped forms are not only pleasing to the eye, but have distinct utilitarian functions. Autumnal leaf coloration is urban man's reminder that winter is on the way. Permanent leaf coloration may jar the sensibilities of certain beholders, but such non-green-leaved trees do have their place. Flowers are desirable, to be sure, in as wide a range of sizes and colors as Nature and the breeder can conspire to develop. Fruit and seed are important too, but more for their absence than presence.

A tree can be ornamental as well as functional. As the architects of the trees of the future, geneticists should not overlook the embellishments that distinguish the Rheims Cathedral from the New York Trade Center.

## RELIABILITY

The key to reliability is testing, testing, and more testing. A recent publication gave 100 years as a reasonable period in which to develop and test a new tree cultivar. None of us would argue that this time span might be desirable, and some of us might even wish to volunteer for the final evaluation phase in 2075. Conversely, few of us are so naive or lacking in ego that we do not expect to make some significant contributions in 1/10 or 1/5 of a century.

What we must do, as best we can, is to compress 100 years of testing into a fraction of that period. Deliberate and controlled tests of pest resistance and tolerance of environmental stress factors should be made as early as possible. Similar tests at a later date can be carried out at the same time as field (or street) tests for "general" survival. Trials of propagation and culture are necessary to insure wide use.

There is not, and may never be, an ideal tree. We can establish "ideal" criteria, but we must be practical enough to realize that we should not postpone the introduction of a superior tree until the ideal is reached. Conversely, we should not hasten to issue a new tree if it is likely that an ever better tree will be forthcoming in a few years' time.

There may be times when, because of inner desires or outside pressures, we may release a cultivar that is not the ultimate ideal, or which has not been tested as strenuously as we would have wished. We shall all do this at one time or another. However, if the cultivar is superior in some traits, and is the best we can hope to offer in the next decade, such release may be justified.

Trees usually outlive their breeders. By careful attention to the goals of improvement, and thorough testing in spite of many difficulties, the trees we leave behind us should be a source of esthetic pleasure and scientific interest for generation to come.

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# A MUNICIPAL ARBORIST SELECTS TREES FOR STREET PLANTING

*by* EDGAR G. REX, *Executive Secretary, New Jersey Federation of Shade Tree Commissions, Cook College, Rutgers University, New Brunswick, N.J.*

*ABSTRACT.* Past experience and published guides provide a basis for present-day selections of trees for planting along municipal streets. Selections that the shade-tree commission of a New Jersey municipality might make, and the reasons therefore, are described briefly.

I SHALL IMPERSONATE the president of a shade-tree commission in a municipality of central New Jersey. This municipality has 35 miles of streets, a tree-planting extent of 70 miles when both sides of each street are included. A recent census of street trees showed that the municipality had about 5,000 trees. Because of Shade-Tree Commission does not directly employ any men, it contracts for all its labor, including that for planting. The Shade-Tree Commission operates on an annual appropriation of $15,000, of which $5,000 are allocated to the purchase and planting of trees. Uncommitted balances of current appropriations revert on December 31 to the municipal treasury.

## SELECTION OF TREES

### Controlling Factors

There are several factors that we have to consider in selecting trees for replacement of removed trees or for establishment of trees in locations not previously planted.

First, trees planted in strips adjacent to street curbs ("lawn strips") should develop crowns that, at least when pruned, provide clearance to a height of 14 feet for vehicular traffic.

Second, selected trees should require little or no protective spraying. Hence, species susceptible to appreciable damage by insects—*Gleditsia* (mimosa and fall webworms) or *Tilia* (resurging populations of Japanese beetle)—are not included.

Third, trees should be adapted to the spaces provided in varying widths of lawn strips. The guide for New Jersey selections is the outline on pages 28-31 of TREES FOR NEW JERSEY, second revision.

Fourth, only about half of the funds available for establishing new trees can be used in the purchase of trees. The other half is needed for planting costs.

### Actual Selections

With the above factors in mind, the Commission compiled the following list of trees to be purchased:

| Number | Species or cultivar, height or caliper, and type of stock | Cost |
|---|---|---|
| | GROUP A—FOR LAWN STRIPS LESS THAN 30 INCHES WIDE | |
| 15 | *Acer campestre*, 6 to 8 feet tall, B-R (bare roots) | $150 |
| 10 | *Oxydendrum arboreum*, 5 to 6 feet tall, B&B (balled and burlapped) | 180 |
| 5 | *Cornus florida* f. *rubra*, 4 to 5 feet tall, B&B | 60 |
| 5 | *Aesculus splendens*, 2 to 2½ inch caliper, B&B | 300 |
| | GROUP B—FOR LAWN STRIPS 2½ TO 4 FEET WIDE | |
| 20 | *Acer platanoides* 'Erectum', 8 to 10 feet tall, B-R | 200 |
| 10 | *Ostrya virginiana*, 6 to 8 feet tall, B-R | 85 |
| 10 | *Aesculus* X *carnea* 'Briotii', 5 to 6 feet tall, B-R | 200 |
| 10 | *Nyssa sylvatica*, 6 to 7 feet tall, B&B | 460 |
| 10 | *Prunus sargentii*, 6 to 8 feet tall, B-R | 77 |
| 10 | *Prunus yedoensis*, 6 to 8 feet tall, B-R | 80 |
| | GROUP C—FOR LAWN STRIPS MORE THAN 4 FEET WIDE | |
| 25 | *Acer rubrum* 'October Glory', 6 to 8 feet tall, B-R | 250 |
| 25 | *Acer saccharum* 'Green Mountain', 6 to 8 feet tall, B-R | 250 |
| 10 | *Quercus acutissima*, 6 to 8 feet tall, B-R | 75 |
| 10 | *Quercus rubra*, 6 to 8 feet tall, B-R | 75 |

In the above list we have 35 trees in group A, 70 in group B, and 70 in group C—a total of 175 trees. The total cost is $2,442, which is within the limit of our budget.

### Comments on Selections

In compiling the list, the Commission noted some comments on each selection. These may be of interest to you:

*Acer campestre.*—A small tree that requires 7 years in the nursery before it is salable. It develops into a fine small tree that suffers little from insect damage and has attractive yellow fall foliage.

*Oxydendrum arboreum.*—A unique tree that has very decorative ericaceous blossoms. In the fall the peach-leaf-like foliage turns blood-red, forming a conspicuous picture in the landscape. Though the tree is slow-growing, over a period of 25 years it will make a good showing.

*Cornus florida* f. *rubra.*—A specialty tree for individual places that need horticultural embellishment. Its pink flowers are very decorative and last for a period of 2 to 3 weeks.

*Aesculus splendens.*—A masterpiece for showmanship. Its panicles of deep red color that appear in late May make this tree a distinction in the municipality.

*Acer platanoides* 'Erectum'.—This is a cultivar propagated from the famous tree in the Mt. Hope cemetery, Rochester, N.Y. It has unique branching habits that fit it well for sites with overhead wires. Its conformation is so distinctive that it cannot be mistaken for any other cultivar of Norway maple.

*Ostrya virginiana.*—A tree noted for its very decorative hop-like fruits, which cover the tree in normal seasons. Its slow growth in diameter is advantageous for sites of limited area within the range of the species.

*Aesculus* X *carnea* 'Briotii'.—A tree of larger proportions than *A. splendens*, but having the same attractive flowers and producing them in the same profusion.

*Nyssa sylvatica.*—A species distinctive in leaf character and exquisite in fall coloration. A row of blackgums (also called sourgums) in typical fall color will not be forgotten, and trees of both sexes are equally attractive.

*Prunus sargentii* and *Prunus yedoensis*.—Species that have made the Tidal Basin in Washington a picture of renown. They do well as street trees and are included in our list for diversity.

*Acer rubrum* 'October Glory'.—A nurseryman's selection for bright fall coloration. Its uniformity in fall coloration differs from the species, which has a mixture of both coloration and timing of leaf coloration.

*Acer saccharum* 'Green Mountain'.—Another nurseryman's selection. Its uniformity of conformation and glossiness of foliage make this cultivar a selection preferred over typical trees of the species.

*Quercus acutissima*.—A relatively new species in street-tree plantings. It holds its foliage throughout the winter months, a factor that may be objectionable. The species is readily established, and its growth rate is good.

*Quercus rubra*.—The standard of oaks for street-tree plantings. Once established, it can be considered a pivotal tree among street trees. The species is comparatively free of insect and disease problems, and its growth rate is excellent.

The foregoing selections of trees are for one community. Each shade-tree commission in each of the various New Jersey municipalities must weigh the advantages and disadvantages of the several species or cultivars recommended in TREES FOR NEW JERSEY STREETS, and then make selections that fit local conditions.

## AVAILABILITY OF SELECTIONS

In some years shade-tree commissions will select tree species or cultivars that they consider highly desirable, but then find that some of their selections are not available in the supplying nurseries. To overcome that problem without forfeiting appropriated money, an escrow contract can be negotiated. This contract sets aside a specific amount of money chargeable to the current appropriation until the contracting nursery produces and delivers the desired trees, possibly 2 to 5 years later. A model for such escrow contracts has been published by the New Jersey Federation of Shade Tree Commissions *(Rex 1966)*.

## CONCLUSION

Shade-tree commissions can draw on accumulated experience and published guides, such as I mentioned, in selecting suitable trees for specific conditions. Research in progress or in prospect will, we hope, provide cultivars superior to those we have to use today in selecting trees for planting along the streets of our municipalities.

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# ESTHETIC CONSIDERATIONS IN THE SELECTION AND USE OF TREES IN THE URBAN ENVIRONMENT

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*ABSTRACT.* The relationship between the physical qualities of trees and esthetics is clarified first by exploring the theory of esthetics; second by a brief overview of the impact of line, form, color, and texture of trees in three categories of compositional scale; and third by the presentation of a digest of esthetic qualities to which people respond on an emotional or intuitive level. The important contributions of the esthetic qualities of trees to various urban situations are outlined. It is suggested that plant scientists should consider the genetic traits that contribute to esthetics as seriously as they do the traits affecting cultural and physiological problems.

THE TITLE OF THIS paper suggests that there is more to consider than physiological and cultural requirements of trees in the urban environment. It suggests the need for an understanding of the esthetic potentials of trees as well.

To gain such an understanding I have divided this paper into three parts. First I will attempt to establish an understanding of the theory of esthetics. The second part is a brief overview of the esthetic qualities of trees. Third, I will suggest where the esthetics of trees can make important contributions toward converting man-made urban areas into a more pleasant environment.

## PHILOSOPHY OF ESTHETICS

Most discussions of esthetics lapse into vague terms, confusion, and disagreement. Estheticians, theorists, critics, philosophers, and artists have long been ensnared in their efforts to find apt, expressive, and critical terms to define, to judge, and to describe the effects of beauty on man. Newton in his book THE MEANING OF BEAUTY (*1950*) stated that, except within the vaguest limits, beauty cannot be described and therefore cannot be defined. It cannot be measured in quality or quantity; yet it is, to man, a recognizable element.

People have come to use the term as if it had physical substance. For this reason, beauty is often considered something you can add to that which is considered ugly. This idea is a misconception. Beauty does not have substance or body in a tangible sense. Rather it has to do with a relationship between an observer and the object observed. Therefore this inquiry into esthetics must examine these two phenomena: the viewing process and the subject being viewed.

The viewing process is concerned with the visual perception of the scene, which causes a personal reaction on the part of the viewer. Two viewers observing the same object or scene will react differently, developing divergent mental images and conflicting value judgments. An individual's perception and assessment of beauty depends not only on the physical properties of the object and its surrounding environment, but also on the human variables of the individual—his experience, his education, his needs and purposes, his prejudices, and his social environment. Although individual value judgments will vary from one another, the degree and extent of these differences will change in time as these human variables change.

It would then seem that the old adage "beauty is in the eye of the beholder" implies that no two people will agree that an object or scene is beautiful. This is not true. It cannot be assumed that, just because individuals vary in how they see an object or scene, it is impossible to create compositions that to all viewers have beauty. The research conducted by Coughlin and Goldstein *(1970)* indicates that there is significant agreement among people on the attractiveness of various scenes and that environmental attractiveness can be determined and analyzed. The study does not mean to imply that each individual will have equally strong feelings about the beauty of an object or scene. It is impossible to have a fixed standard or uniform response because there is no common fund of the human variables.

As a consequence of these variables, the esthetics of a design cannot be predicted precisely; yet it is possible to have general agreement. This is because the scene or object has several common factors that contribute to the pleasure and intensity of emotion of most observers.

## PHYSICAL QUALITIES AFFECTING ESTHETICS

Emotional responses to objects or scenes are based on the physical qualities of the object. The latter can be separated into (1) line and form, (2) color, and (3) texture. Every object has these physical qualities. They are the raw materials of esthetics and beauty. In fact, they are the only elements that can be manipulated by the designer to create satisfying and beautiful compositions.

Since these physical properties are the basis of judging esthetics and beauty, it might seem logical to assume that the viewer analytically evaluates each physical quality. This is not the case. Only the most critical and trained observer analyzes and reasons good or bad on the basis of each physical quality isolated from the other.

The average viewer casually views an object or scene and reacts to the composite effect of the physical qualities, not just to one component. The process of viewing and reacting to what is seen is both an unconscious and conscious act.

The unconscious phase involves feeling —an involuntary response of pleasure or disgust on first observation. The reaction is based on our sensory perception through sight, touch, hearing, smell and taste. The unconscious phase is followed by the conscious response. At this point the viewer starts to compare with past experience. His judgment will be conditioned by familiarity, prejudices, knowledge, and background.

It should be understood that unconscious (feeling) and conscious (thinking)

are familiar terms that permit the concept of viewing to be established. However, they should not be regarded as separate and distinct functions that operate independently. Within the human mind, the two phases merge into a single process that cannot be divided.

Therefore in establishing the theory and philosophy of esthetics, it should be recognized that esthetic values are appreciated through the senses of sight, sound, smell, and touch, but that beauty itself is dependent upon the physical properties of line and form, color, and texture of objects. For this reason, it is necessary to examine these physical qualities as they relate to trees.

The basic structure of a tree, its pattern of lines, the contour outline of its form, and its basic habit of growth are discussed to provide a basis for determining which types are suitable in the urban setting.

### Line and Form

*Characteristics.*—Line and form are particularly important because these qualities are the most predictable and the most permanent regardless of season. Line is essentially an expression of form, form is an expression of line. They are separated here for discussion purposes only. Among trees, lines are straight or curved, vertical or horizontal or oblique. The trunk and main branches determine the line and mass of a tree, the shadow patterns both internally and externally, and the character and personality of the tree.

Form is the mass or volume of a tree that expresses itself in all three directions of space. The extremes of form—ranging from rigidly erect to weeping—provide a wide palette of materials from which to choose. It is the form of a tree that is responsible for the feeling and emotional appeal that is conveyed to the viewer.

*Classification.*—Lines can be classed as horizontal, vertical, or oblique, and forms of trees as columnar, rounded, vase-shaped or broad-rounded, pyramidal, irregular, or weeping. Horizontal lines emphasize extent and are restful; vertical lines are severe and provide a feeling of height; oblique lines suggest movement. Columnar forms of trees have either rounded or pointed tops and provide contrast. Rounded forms are pleasing and usually have dense crowns. Vase-shaped forms branch high so there is usable ground space below, are compatible with most plant forms, and blend well with architecture. Pyramidal forms accent the spire top, provide strong contrast, are difficult to harmonize with other plants, but are effective as specimen plants. Irregular forms provide both interest and contrast to architectural masses because of variable outline. Weeping forms are unnatural to some people, but are unique, lead attention to the ground area, and are effective against hard lines of architecture.

### Color

*Characteristics.*—Flowers, fruit, twigs, bark, and foliage are the sources of color in trees. Because flower and fruit colors are seasonal and of short duration, they cannot be considered as primary design elements. Twig color becomes a major factor during winter months if deciduous materials are being used. But leaf color in both subtropical and temperate plant regions is an important consideration.

Foliage, although predominately green, can be classified according to its varying shades. In both subtropical and temperate plants, the following greens are common: gray-green, red-green, yellow-green, blue-green, black-green, and emerald green (true spectrum green). In some cases these are subtle variations of green and in others, they are obvious derivations from spectrum green. Regardless of the degree of variation, they are still considered green colors. In most situations the use of color in the landscape should be built around these variations of green.

All colors in the landscape are subject to one further modification that affects a person's experience of the color. This is

the variation between true local color and the color perceived as a result of atmospheric interferences between the light source (the sun) and the object. The earth's atmosphere varies the effects of color with every hour. At sunrise and sunset there is a violent disturbance of local color. For example the sun turns to crimson, the sky to gold, and clouds to rose and lilac. The chromatic interference resulting from atmospheric causes produces significant changes in color. Therefore color is more difficult to grasp intuitively as compared to form, which is not subject to atmospheric variations.

Nevertheless, color compositions should be based on the predominant foliage color of green and its derivations. To do otherwise would be counter to nature's own use of color. Nature is timid in her use of warm colors (red, yellow, orange), which are limited to small amounts such as flowers and berries. Our use of color should not attempt to rearrange this balance of color harmony.

This leads us to horticultural introductions in which unnatural colors have been developed—garish reds, jarring variegations, and vivid blue, to name a few. These abnormal colors should not be the goal of breeding and selection. They do not fit into the urban landscape—a landscape which is already overpoweringly artificial. Such foliage colors assume a prominence that is not warranted and further underscore man's separation from nature.

*Classification.*—The varying shades of green can be broken down into seven classes:

1. Dark green appears somber but combines well with architecture.
2. Light green is effective in expanding apparent size of space and lightening low-light areas.
3. Gray-green is also effective in expanding apparent size of space, combines well with vivid colors of buildings, but conveys a cold feeling.
4. Blue-green combines well with other foliage colors, suggests coolness and calmness.
5. Red-green offers a spark of vitality and feeling of warmth to an area, but reduces its apparent size.
6. Yellow-green blends well with other colors, brightens shadowy areas, and offers a cheerful effect.
7. Black-green seems somber and formal, but combines well with other foliage colors and with architecture.

### Texture

*Characteristics.*—Texture in trees is judged on the basis of visual qualities instead of tactile experience. It is the arrangement and the character of the component parts that results in a texture effect.

Plant textures vary according to the distance from which the plant is viewed. In the near view, texture is the result of size and spacing of leaves and twigs, shape and surface quality of leaves, and length and stiffness of petioles. In the far view, texture depends on the same qualities listed in the near view. However, as the individual detail is lost, texture results from the light and shadow of the plant or plant masses.

Too often texture is overlooked in the selection and use of trees, probably because it is a variable quality subject to modification by season, age, climate, and atmosphere. It should not be ignored, particularly in the urban landscape. Effectively used, it can exploit and heighten the character and visual impact of the tree.

Texture can be used to establish a harmony throughout the urban space by repeating the texture of the surrounding elements in the space, or it can be used to create variety and accent. Texture can also be used to modify distance and the size of the space. For example, fine textures recede, thereby increasing the apparent size of the space. Coarse textures are visually dominant, resulting in a reduction in the apparent size of the space.

*Classification.*—Texture can be divided into five classes: fine, medium-fine, medium, medium-coarse, and coarse. Fine

textures are delicate and airy, provide a refined appearance, complement smooth surfaces, and soften and blend with harsh lines of architectural masses. Coarse textures blend well with rugged, heavy materials, are dominant and effective even when viewed from a distance, but tend to dwarf areas. All other classes are gradational between these two extremes.

### Design Context

To aid in the use of these qualities as a tool for judging and selecting trees, it is now necessary to discuss the use of line, form, color, and texture from a design context. Such a discussion requires an understanding of the visual impact of these qualities on the basis of static and kinetic observation and scale. The potential visual strength and visual impact of each esthetic quality on urban space varies according to the movement of the observer and the distance between the object and the observer.

The landscape may be viewed from points or locations that allow static or stationary perception. In this case the designer can exercise great control over the impact of line, form, color, and texture since it will always be seen from one direction and from an unvarying distance. Which physical quality emerges as the strongest depends on the designer.

Most often the landscape is experienced while the observer is in motion. The speed of this motion becomes a critical factor in evaluating visual impact of the physical qualities. If the observer is moving through the landscape in a vehicle, the high rate of speed precludes the opportunity for careful and detailed observation of the physical qualities. In this situation form has the greatest impact, followed by line and color, and texture is the weakest. This ranking varies substantially when considered on the basis of the observer's motion resulting from walking at a rate of 2 to 3 miles per hour. In this case the distances between the observer and that which is being observed will determine which of the three physical qualities will have the greatest impact.

The basis for judging visual impact is dependent upon the compositional scale of the design. In any design there are three compositional scales: foreground, middle-ground, and background. As we discuss each of these compositional scales, we must also consider the physical qualities on each scale.

The foreground space is that close to the viewer. Closeness allows the details of building materials and trees to be seen. At this scale, the intricate structure of line in twig and branching produces strong asculptural pattern in space and a three-dimensional filagree pattern against architectural structures. Form is important only when the total tree can be perceived by the viewer. Such small trees must have an interesting silhouette and sculptural shape. The color of bark, twigs, foliage, flowers, and fruit have strong impact, as does texture. Both must be carefully planned and patterned to avoid overuse and jarring results.

The middle-ground scale is the transition between the close-up detailing of the foreground and the overall general composition of the background. All of the physical qualities come into play, but form will have greater strength. For example, the line of branches begins to merge into form; color details are lost except for the foliage contrasts of the various shades of green; and texture is a general effect of foliage and structure rather than details of leaf and twig. The added distance between the viewer and the tree permits easier perception of the total tree, further enhancing the importance of form. Therefore tree forms can be selected to contrast with surrounding architecture, to offset architecture as a foil, or to complement it by repeating the dominant forms, masses, or lines.

Background is the basic structure and framework of the composition and is a greater distance from the viewer. Although it will already be structured by surrounding urban elements—buildings, roads, signs, walls, etc.—the trees should mold, define, and reinforce the volume of space contained within the composition.

In this situation, line is evident only as a contour outline of the tree's form or as the result of several trees combined as a mass. Color has minimal impact except for the general impression of green without the subtle variations noted earlier. Texture, however, is somewhat more important because it is perceived as light and shadow effects resulting from line, color, and form. But once again form asserts itself over all the other physical qualities. Tree forms in the background should be presented with clarity, boldness, and strength—and yet always with simplicity.

It should be noted that, at certain times of the day or year, a normally weaker element can assume temporary strength to the point where it dominates the scene. For example, seasonal floral displays or spectacular fall color, either of which could overpower form at any scale.

## EMOTIONAL QUALITIES AFFECTING ESTHETICS

There are other esthetic qualities associated with trees that result from line, form, color, and texture, but are conveyed and perceived more on the emotional level than on the rational and analytical evaluation of the physical qualities. The following is a digest of these qualities. They can be utilized in any urban situation; it is only a matter of determining which is appropriate. But in each case it is a combination of the physical qualities of the tree and the element of compositional scale that produce the esthetically desirable effects.

*Space identification* results from trees being used to establish a feeling or sense of place, possession, and movement. *Sense of place* is an encounter between the individual and place that is dramatic, simple, and impressive—space in which a person is emotionally secure. *Sense of possession* involves shade, shelter, and visual quality of space in order for people to use it and take possession of it. *Sense of movement* results from space defined by trees to outline a corridor of movement that eliminates confusion and indecision on the part of the user.

*Enclosure and space definition* is the shaping of outdoor spaces by utilizing trees. Enclosures created by trees are rarely total and complete. Trees function more on the basis of suggestion rather than by providing complete visual stops. In the near view, tree trunks provide a colonnade that defines space and implies containment, yet the gaps between trunks reveal what is beyond. In the far view the combination of trunks and foliage tend to merge, suggesting a total and complete enclosure.

The details of line and form, color, and texture of the trees used for enclosure have importance at a distance of 40 feet or less. Beyond 40 feet the composite effect of the total mass assumes importance.

*Visual control orientation*, focus, and sense of direction are attributes of visual control through the use of trees. *Orientation* is the use of trees to stimulate a reaction such as "I am enclosed", "I am exposed", "I am in it", "I am outside it", or "I am below it". Trees are also obvious devices to serve as a point of reference—"over there" or "here at the tree" or "under the tree". *Focus* is the transferance of attention. For example, a tree placed near an architectural element seizes our eye and holds our interest, resulting in a strong focus of attention. *Sense of direction* is control over the extent of the observer's view. It includes enframement of a vista, the partial screening of a vista, the linking of the near view with the far view, and the closed vista.

Enframement involves the use of trees to force viewing a special feature or remote landscape.

Linking the near view with the far depends on compartmentalizing the overall view, forcing the observer to see only sections of the total scene. When trees are arranged so the trunks form a series of "windows", the remote area is framed

into a series of "pictures". This directs the observer's attention to the details of the remote scene.

Partial screening of a feature or vista utilizes the crown of a tree to withhold the total view until the observer has moved past the tree. This technique works well when the feature is large enough to be partially viewed over or around the screening tree. This introduces intrigue and curiosity that is climaxed by the dramatic impact of the full view once one has passed the tree.

Finally, a blocked vista limits the observer's view to the immediate space he presently occupies. The result is added interest in the immediate environment.

Trees selected for screening or blocking of vistas should have strong form and be relatively dense. At the same time they should have interesting details for the nearby observer.

*Truncation* is the use of trees to mask the upper portion of buildings so that the building is not seen in its entirety. This break of the vertical mass directs attention to the space at eye level (the area below the tree's crown). The immediate space is no longer overwhelming to a person because the dwarfing influence of architecture is reduced by truncation.

*The dramatic* involves incidence, sequence, anticipation, infinity, and illusion. Establishing an *incidence* involves the capturing of the eye and attention in the midst of a monotonous field of vision. A continuous row of buildings quickly becomes boring because of number and dominance. If such a scene is interrupted by a tree or group of trees, the total scene has interest for the viewer. *Sequence* is a process of revealing a succession of views by having trees arranged to suggest a path of visual or physical movement. *Anticipation* is the exploitation of human inquisitiveness. Instead of giving orientation and meaning to the scene, trees are used to arouse one's curiosity as to what will be seen next after passing beyond the visual block. An attempt to use trees to expand the boundary of the immediate area provides a *sense of infinity*. Trees with strong line and form can direct the eye and attention, suggesting an expansion of size and infinity. *Illusion* involves suggestion and contradiction of perception. Past experience has taught us what we expect to perceive in depth, size, and distance; but by skillful placement or juxtaposition of trees, the visual experience can contradict the intellectual. If carefully handled, it can be intriguing and delightful.

## ADDITIONAL CHARACTERISTICS AFFECTING ESTHETICS

Some additional characteristics of trees that also must be included in our digest of esthetic quality include silhouette, sculptural effect, shadows, reflections, intricacy, geometry, scale, foil, intimacy, and detail. A brief description of each follows.

1. Silhouette.—View of a tree as seen against the sky or building. It is a quality that is dynamic and expressive as well as appealing and satisfying.
2. Sculptural quality.—Refers to the three-dimensional form of the tree. It may be bold or varied, yet always interesting because of the changing visual angle that results from the movement of the observer.
3. Shadows.—Two-dimensional elements that have tremendous potential for esthetic effects. Shadows on the vertical walls of architectural or paved surfaces of the ground add detail, contrast, and animation to the man-made surfaces.
4. Reflections. — Two-dimensional patterns, like shadows, but created by water, glass, and other mirror-like surfaces. Surfaces that upon quick glance have no significance come to life with the interesting and provocative pattern of shadow and reflection.
5. Intricacy.—A quality relating to the natural yet sometimes curious branching pattern and general habit of growth of the tree. For the observer,

this quality is sometimes curious and abstract, yet impressive and meaningful.

6. Geometry.—The interaction of the tree form with architecture, sky, and space. Geometry can transform the landscape by the scale it establishes and by the significance it gains from contrast with the surrounding environment.

## USE OF TREES FOR ESTHETICS AND UTILITY

### Combining Both Functions

The foregoing discussion of the theory of esthetics and the cataloging of esthetic qualities of trees provide us with the neccessary background information to consider now the various urban situations in which trees and their intrinsic qualities can be used effectively. We need to talk not only about esthetics but also about utilitarian function. There can be no dichotomy between the two. For too long, trees have been promoted on the basis of appealing to the imagination and emotions to the complete exclusion of reason and function. Both utilitarian and esthetic functions must be considered and exploited. Only on this basis can we convince the businessman, the developer, and the politician of the need for trees in the urban environment.

What is being suggested is *practical esthetics*. It is based upon how the physical qualities can be grouped and patterned in the urban environment to provide a satisfying and visually pleasing appearance and fulfill a utilitarian function. To do this it is necessary to establish two concepts.

The first concept is that people develop an intuition as to what is beautiful. Theoretically it is possible to explain the visual aspect of every object or scene on the basis of the physical qualities of materials. But in actual practice the relationships among line, form, color, and texture are grasped intuitively; and this intuition is sufficient for people's enjoyment.

The second concept is that esthetic value judgments are made on the character and type of the total landscape environment (architectural materials, trees, and space) rather than on the detailed arrangement of individual elements in the landscape scene.

As a first step towards establishing practical esthetics, we have to accept the premise that trees are uniquely capable of (1) creating and defining space, (2) establishing the scale of the area, and (3) developing a harmony with the surrounding urban environment. Practical esthetics involves more than merely filling open spaces with trees. Urban situations are so diverse in size and character that each calls for different techniques and criteria in selecting and using trees. There should not be one constant method or pattern. The decisions should be based on the tree's line, form, color, and texture; the interplay of spatial areas in plan and elevation; and the tree's relation to buildings, to the "offscape" and to human use of the space.

### Trees for Different Urban Settings

The typical urban situations in which trees should be included can be grouped into (1) the single site, (2) the project site, (3) open space areas, and (4) the connector system. How trees, a basic material, are used for esthetics and function depends on many variables that make each site unique.

The *single site* usually involves a small unit of land on which there is one building with limited open space, such as a plaza. The goal for its development should be to define and reinforce the space, making the site pleasing and delightful to the user. Therefore, the size of the tree must be large enough to have a good scale relationship with the building. If it is a high-rise structure, the tree's crown should be massive and large enough to truncate the towering architec-

ture so that the building will be viewed as a backdrop for foliage and branches.

Because the site will be viewed mostly by pedestrians, the trees selected should contribute interest in line, branching patterns, texture, and color (for foreground views). These esthetic qualities provide delightful contrasts to the hard surfaces, harsh lines, and cold materials of the architecture.

The *project site* usually includes more than one building and has sidewalks, streets, and parking areas. Shopping centers, industrial parks, and housing projects are examples of project sites. The goal in the use of trees should be to facilitate visual identification, to create a memorable scene and to establish the feeling of a sense of place.

Often this landscape is characterized by an openness between buildings, roads, and walks. Trees can be used to provide continuity to the spaces and to articulate the form of space simply by dividing it into smaller units. As trees will be viewed mostly as background, their forms will be a critical esthetic factor. Similarly, parking lots are large and incomprehensible. They can be given architectural form through the repeated use of tree forms that are visually strong. An added functional benefit will be to give order and pattern to the movement and parking of cars in the lot.

Trees may also be used to direct the movement of people. When the direction of movement is defined, the user can have a fuller enjoyment of space and be relieved of confusion and indecision.

Finally, trees can be used to control spatial experiences, to interpret the use of the space and to orient the user. All of these considerations require an evaluation of line, form, color, and texture on the basis of how well selected trees will accomplish utilitarian requirements and at the same time heighten the user's visual and emotional experiences. Which qualities will have priority will depend on the proximity of the tree to the observer and his rate of movement through the space.

*Open spaces* are varied and serve different needs and functions. Open space may be a greenbelt for separating or blending different parts of the city. It may be open lands for active and passive recreation. Or it may be a large-scale plaza for a variety of mixed uses such as sitting, walking, playing, eating, concerts, and art shows.

Greenbelts can be used as a transition or buffer between various districts—as commercial, residential, industrial, recreational, and educational. Trees can be used as either barriers or elements of transition, depending on the degree of physical and visual penetration they permit. The individual tree's form, color, or texture is not important, but those of the aggregate are. The composition must be carefully conceived to convey a harmonious and visually satisfying combination of the physical qualities.

Parks are unique environments in the city because they are distinctly different types of landscapes. They are deliberately planned alternatives to the dominant man-built environment. Here trees should be used in two ways. First, they should establish a green outdoor environment, a view or a background from a distance, and the visual impact will be from the combined appearance of all the trees. Second, the same trees should be used in an architectural and space-organizing role, which requires interesting pattern and detail for the foreground and middleground scales.

Major plazas and open malls should capitalize on human activity—sitting, walking, chatting, people-watching, etc. To ensure active use of such space, it must have a good microclimate, which is a function trees easily perform. Plazas must have a sequence of subdivided interior spaces that give a sense of intimacy, contrast, leisure, and activity. Trees can serve as subdividers while adding character to the skyline, providing

shelter and conveying a sense of place. Utilizing physical qualities and compositional scales, the esthetic use of trees should clarify and express the emotional mood to the spaces and visually support the activities.

The *connector system* involves streets that extend throughout the city, connecting many diverse elements. The connector system is potentially the unifying element of an urban scene that is awkwardly fragmented into separate uses and zones. Esthetic qualities of trees provide one of the most powerful agents for unifying and joining the city.

The criteria for tree selection will be based upon the character of the street—residential, arterial, strip-commercial, and pedestrian-shopping.

The residential street provides access to homes. It is the path of cars and utilities and, to a lesser extent, pedestrians. Here trees should mask utilities without interference, separate pedestrians from automobiles, and soften and blend varying architectural styles into a harmonious whole.

The arterial street has a high volume of traffic and provides a higher speed of travel, while bisecting the whole range of urban spaces. Arterial streets may develop into strip-commercial areas characterized by an inordinate number of oversized, garish, and flashing signs in front of a tawdry collection of franchise architecture and ill-matched buildings. Trees can do little to solve the overbearing visual and traffic problems, but they can ameliorate them. A basic attraction of the arterial street for commercial activities is the high degree of visibility, and tree plantings should not reduce it. Therefore, the criteria for esthetics and function will be large trees that permit visual penetration at windshield height to areas beyond.

For arterial streets in general, selection of trees should consider speeds of the observers. The importance of form is obvious. Whether the crown should be open or dense depends on how much visual penetration is desired beyond the street corridor. Trees do not have to be regularly spaced at 30 to 40 feet to be effective. In fact utilities, curb cuts, and other physical elements usually prevent such rhythmic repetition. Nevertheless the introduction of trees wherever space is available creates visually pleasing effects along a monotonous street. Such trees should be sharp in silhouette feature, strong in texture, line, and possibly color, so as to add variety and interest.

The gridiron pattern of most urban streets allows for scanning the total scene within seconds, and the observer is soon bored. Trees of special interest in line, form, texture, and color can often be used to close off the endless vista. The result is containment of vision and intrigue for the observer.

Varying the street-tree pattern by alternating trees in a projection-and-recession pattern eliminates the effects of a straight-line green facade imposed on straight-line architectural facades. This provides an intricacy and pattern that is stimulating and enjoyable. Form and habit of growth are primary considerations.

Trees for minor streets should be used in much the same way as for arterial streets. However, on narrow streets, trees may be limited to one side, alternating sides by blocks. For narrow streets and small buildings, relatively small trees are preferred.

The pedestrian shopping street, as in the central business district, performs many functions: a thoroughfare, storage of parked cars, a servicing and delivery access to stores, and a space for pedestrian shoppers. Here the observer moves at pedestrian speed in a space classified as foreground scale. Trees of high interest in the details would be appropriate. At the same time trees should function to separate cars from pedestrians, to provide human scale in the midst of oversized buildings, to serve as focal points, as vistas and as places to sit, and to harmonize variable styles of architecture and a diverse and unorganized scene.

## CONCLUSION

I have presented the theory of esthetics, an outline of physical qualities as units for manipulation to achieve esthetic results, and a catalog of esthetic qualities as they relate to trees and typical urban sites. To be meaningful, this discussion must be carried one step further, suggesting an approach for breeding and selecting of plants for different regions of the country.

Since esthetic impact results from the relationship between the physical qualities (line, form, color, texture) and the observer, the designer selects trees for their suitability in functional requirement and for their fitness to the esthetic needs of urban space. The latter implies the right form and habit of growth, the right color, and the right texture. These are genetic traits that the plant scientist can manipulate in his efforts to breed and select new trees to meet this very demanding man-made environment.

Any recommendation as to what plant breeders should be striving for in terms of form, habit, color, and texture must be developed on a regional basis, using vegetation that is common to the area as a basis of evaluation. Such an analysis should take into account the distinctive character of the predominant regional vegetation. This will then serve as a basis for determining what is needed in new introductions to provide a complete palette of plants that also meet other use criteria. It will also serve as a measure for evaluating the line, form, color, and texture of new introductions. Care must be taken to avoid the exotic and the unnatural. Instead the new trees must have a tolerance for urban environments, yet have sufficient similarities to the existing kinds of trees to assure that the distinctive character and sense of local identity are not lost. The importance of developing a tree planting that is in harmony not only with the immediate space, but with the surrounding landscape as well, cannot be overemphasized.

Harmony refers to the selection of trees that are appropriate in the degree of enrichment and in their role of strengthening and reinforcing the function and purpose of the space. Harmony's influence is not restricted, however, just to the space being developed. It also relates to how well the space being developed harmonizes with the surrounding landscape.

The rational and emotional level of aesthetics as discussed in this paper have had to be limited by necessity. This paper has dealt with the tangible physical qualities of aesthetics and the fact that they have value and emotional meaning to the observer. These two aesthetic concepts create possibilities for the plant breeder to add significance and value to new introductions.

In aspiring to assist breeders in aesthetic engineering, designers must learn how to define the design problems involved in selecting trees for urban use. In this way the solutions will respond to more than just cultural and physiological problems. This symposium is, in my opinion, an important beginning to bring into the breeding process an explicitness about its aesthetic consequences.

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# SOME PSYCHOLOGICAL AND SOCIAL ASPECTS OF TREES IN THE CITY

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*ABSTRACT.* Recent studies in environmental perception indicate that the meaning and function of forest vegetation in the city may not be the same for urban residents as it is for rural and suburban residents. These studies suggest advantages for collaboration between behavioral scientists and forest geneticists in planning future research. Several possible psychological and social benefits of urban trees are discussed. Further behavioral studies may indicate desired attributes of trees bred especially for inner-city environments.

VISIONARY MEN like William Penn and Thomas Jefferson stressed the need for wooded tracts among the shops and residences of cities. However, until the late 19th century, most American cities contained few woodland tracts or parks. But with the conception and development of Central Park in New York, trees, grass, and water were retained in the heart of the city and were made accessible to residents of the inner city for pleasure and relaxation. By the turn of the century, similar parks had been designed for many other cities—Albany, Baltimore, Hartford, Philadelphia, and Pittsburgh among others (*Zube 1971*).

Now questions are being asked about these parks. In a recent critique of the nonuse of neighborhood parks Gold *(1972)* noted that parks designed for middle-class white patrons of the inner city in 1900 may no longer be relevant to current residents of other ethnic and racial backgrounds.

For a long time urban planners and designers have assumed that people have an innate and deep-seated need for intimate contact with nature. This need may be a learned cultural trait, characteristic of western civilization. The concept of the pastoral ideal has been a persistent theme throughout western civilization (*Marx 1964*), expressed even now by those who identify with the dominant culture. However, the contention that all people, adults and children, have an innate need for contact with nature is debatable and without strong empirical support.

Recent evidence suggests that the meaning of trees and forests for urban residents may not be the same as for

their rural counterparts. One study has found that residents of the inner city tend to evaluate scenes at the urban fringe differently than do suburban and rural residents. The scenes used in the study were predominantly natural, but included examples of a residential subdivision and a commercial-strip development. The scenic ratings of the inner-city subgroup were more likely to represent the extreme range of values in both natural and urbanized scenes. The group of adult inner-city residents was too small a sample on which to base firm conclusions, but the data do indicate that there may be strong differences in the way these citizens perceive and evaluate outdoor environments (*Zube and others 1974*).

In a pilot study to measure the quality of life in urban and rural counties in New York State, Milbrath and Sahr[1] found that urban people placed more importance on upward mobility and material consumption than did their rural counterparts. Urban people also placed less importance on natural outdoor recreation, landform and topography, unspoiled nature, and variety of wildlife than did people living in a rural county in the Adirondack Mountains. Despite these lifestyle differences in the two counties, there was considerable agreement on basically important things such as clean water, medical care, security, privacy, comfort, and freedom.

This suggests that we should be wary of imposing on urban residents our values for trees and forest vegetation that do not have meaning for them. There does not seem to be sufficient information about the values of forest vegetation for inner-city residents. Before we set out to design better trees for urban environments, we need to ask some basic questions. What are the indicators of the quality of life in urban environments? How do urban residents perceive their physical surroundings? And what importance, if any, do trees and forest vegetation have in their lifestyle?

## TREES FOR CHILDREN'S PLAY

One psychological benefit from trees in cities is their potential use for children's play. We know from our own experience and from direct observation that children in rural and suburban environments use trees in their play. They climb in trees, hide in trees, build in trees, and swing from trees. Would children living in inner-city neighborhoods use trees in the same way?

As a part of another study, our colleague Robert Williamson informally interviewed a number of rural, suburban, and inner-city children. Among other things, he asked them: "What does a tree mean to you?" The children's answers were surprising. The rural and suburban children tended to view trees as either a place to play (climbing, hiding, or building tree forts) or in a general way that might be termed a nonutilitarian response ("You can talk to a tree," said one child).

The responses of the inner-city children were quite different. None of these children responded to trees in a playful or esthetic sense. Almost invariably they responded that trees were a source of wood—raw material to be used in housing, floors, furniture, and so on. The response of city children to trees may have been influenced by their lack of contact with trees and forests. The number of trees in their neighborhoods may have been too few or too large to climb, or were surrounded by fences.

Assuming that inner-city children would enjoy playing in trees if they were available and accessible, we could give some thought to the attributes of trees that are conducive to play, such as smooth bark and stout low limbs close together for climbing.

[1] Lester W. Milbrath and Robert C. Sahr reported the results of their study in a paper, "Perceptions of Environmental Quality" delivered at the VIII World Congress of the International Sociological Association in Toronto, Canada, on 23 August 1974.

## TREES AS SOURCES OF INFORMATION

One value of trees in cities that is seldom considered is as a source of information. We are using "information" here in the technical sense of information theory *(Shannon and Weaver 1949)*. Here, rather than being considered as something to be obtained from a magazine or a television news show, information can be conceived as signals that come to a person from his or her environment in terms of "bits," often in a nonverbal manner.

Cities, despite all claims for their infinite variety, tend to be places of extreme regularity. Street systems are usually laid out in a grid system, buildings tend to be rectangular and symmetrical, and there is a certain sense of visual sameness. There is little information in the sense of novel stimuli, change, or complexity. For residents of such a section, this low level of information can produce monotony, boredom, or tedium. Prolonged exposure to information-deficient environments creates pathological problems *(Heron 1957)*. The problem is to increase the amount of information in these environments by providing novelty, change, motion, and complexity. Trees can help accomplish this in a variety of ways. Moreover, some kinds of trees may be more effective than others.

A variety of factors associated with the tree itself are important in producing information. One is shape. An irregular shape contains more information than a regular shape. Consider, for instance, the irregular shape of a mature, open-grown, white pine (*Pinus strobus*) relative to the regular shape of a spruce (*Picea* spp.).

A second factor associated with the tree itself is color. Colorful flowers add to the novelty of a tree. In the fullmoon maple (*Acer japonica*) the foliage color is novel, and many other deciduous trees have color in the fall. This seems to imply that deciduous trees contain more information than coniferous trees. Overall, this may be true. Yet the color of coniferous trees makes an important contribution to the bleak landscape of winter.

Motion (and especially leaf motion) is another factor that can increase the amount of information. Some trees have rigid branches and leaves, while others have more supple limbs and leaves. Consider the quaking aspen (*Populus tremuloides*) when even the slightest breeze stirs the leaves and provides much variation in light and dark.

A fourth information factor is seasonal change. Trees, especially deciduous ones, contribute to information-deficient environments by signaling the change of the seasons. From the first buds of spring, through the luxuriant summer foliage, to the cold and brilliant colors of autumn, deciduous trees signal the onset of the seasons.

Factors external to the trees themselves may also be important in providing novelty or change. On how many city streets have we seen one species of tree planted at evenly spaced intervals? It might be better to vary this spacing so that several trees occur together after an open space. Or the species could be varied as well.

Then, too, we cannot afford to consider only the single tree: the context it appears in is important too. Texture and contrast are both important variables in increasing the amount of information.

These are but a few of the information factors associated with city trees. The key point is that trees can and do serve useful roles in providing information in otherwise information-deficient environments. Such uses of trees merit future research attention.

## SHADE FOR OUTDOOR ACTIVITIES

The need for shade in the heart of cities may seem obvious. In the city where the form of the outdoor environment is floor and walls and pavement

and buildings, the shading from the high summer sun is only a narrow strip along a wall. There are few ceilings or canopies that shade the pavement and allow movement and activities to occur beneath. Mature single trees and clusters of trees provide shelter from the sun for whatever human activities may occur beneath their branches—a quiet conversation, a picnic, a game of tag, or a pickup game of basketball.

Shade trees and cities are not always compatible. In fact, most trees exist in the heart of cities only by the deliberate action of man; they must be planted and cultivated. City trees hardly constitute what we might call a forest, but natural regeneration does occur in time on vacant lots, along steep unbuildable slopes, and in deserted alleys. Such natural vegetation is more like weeds: fast-growing, tolerant of heat, shade, drought, and meager soil. Such trees are often scrawny, yet some people appreciate them even so because of the scarcity.

In conclusion, we suggest a possible contribution of forest-genetics research by using a hypothetical situation. A park planner in New York City recently posed this problem. In a severely depressed section of Queens, many apartment houses had been taken over by the city for overdue taxes and torn down. Vacant lots are new scattered over many city blocks. What could urban foresters do with these vacant city-owned lots to improve the physical environment that didn't involve money? The obvious answer is—not much. Vacant land in cities may not remain vacant for long. Trees take time to grow; transplanting large trees costs plenty. And then who is to say that the trees wouldn't be vandalized, mutilated, or cut down in spiteful contempt?

Assuming that some group of persons in a neighborhood cared enough to plant trees on the vacant lot and watch over them, what trees could grow there? Planted as seed or seedlings, what species could tolerate low moisture and poor soil yet provide shade in a few years? Fast-growing boxelder (*Acer negundo*), quaking aspen, or the tree-of-heaven (*Ailanthus altissima*) could fill the bill. Perhaps particular attributes desired by urban residents could be bred into such trees. Perhaps some of the rapid growth could be sacrificed for sturdier branches that children could climb in, or perhaps the tree-of-heaven could be deodorized.

For urban residents who cannot escape the heat of the city in the summer, fast-growing trees could provide relatively instant shade in 3 to 5 years. Shade for vacant lots could provide a cool place for elders to meet, for teens to rap, and for kids to pedal their trikes or climb to a tree house while mothers can watch them from shaded benches. Outdoor shade in summer might make a vacant lot or two into social meeting places for a neighborhood of strangers, a place to go outdoors that is close to home. Planting city-owned vacant lots to trees and other vegetation, however temporary their status may be, could make neighborhoods more stimulating and could satisfy unmet needs for outdoor activities close to home.

The research question for behavioral scientists is to find out what attributes of forest vegetation in the city are perceived as desirable by urban residents. The question for geneticists is how to improve hardy weed trees that already have a foothold among the cracks in the concrete. Research in both areas would gain from mutual cooperation.

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# SELECTION OF TREES FOR MODIFYING METROPOLITAN CLIMATES

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*ABSTRACT.* The current state of knowledge about effects of trees on microscale and mesoscale metropolitan climate is discussed. Emphasis is placed on the potential role of trees in ameliorating climate for human thermal comfort outdoors and for reducing consumption of energy for heating and air-conditioning buildings. The physics of the energy exchanges that control metropolitan climate are summarized. Suggestions are made for the selection of species and kinds of trees for modifying the climate in metropolitan areas.

WHAT ARE THE REASONS for concern over the possible roles that trees play in moderating or controlling metropolitan climates? Trees can directly affect human comfort outdoors as well as the energy required for maintaining comfortable temperatures indoors. Also by altering climate, trees may indirectly affect dispersion of pollutants and distribution of rainfall. We will concentrate on the more direct effects of trees in metropolitan areas.

Much has been written about trees and the climate of urban areas. Most of this information has been developed from subjective evaluations of the influence of trees or has been extrapolated from experiments conducted in forest conditions. This has led to some quantitative and even some qualitative misinterpretations of the effects of trees on climate. Other misinformation is due to a lack of communication between physical scientists and urban designers.

Recently, research has been completed that more accurately describes how trees ameliorate climates of urban areas. In particular, insight has been gained into the effects of trees on environmental conditions important to "human thermal comfort" and the heating and cooling of buildings. However, it is still not possible to do more than make general suggestions about selecting tree species for modifying urban climates.

One of our primary goals in this paper

is to provide background information about the physical basis for selection of trees to modify climate. The effects of trees on metropolitan climates have also been discussed by Federer *(1971)*, Heisler *(1974, 1975)*, Herrington and others *(1972)*, and Herrington *(1973)*.

## THE PHYSICS OF CLIMATE AND CLIMATE MODIFICATION

### Scales of Climate

Climate is usually defined in terms of averages of air temperature, relative humidity, wind speed and direction, solar radiation, cloudiness, precipitation, etc. The average can take place over various times. The usual connotation of climate is that it is the average taken over ten's of years and over an area of several hundred square miles. Partly to avoid local surface effects, National Weather Service observations of temperature and humidity are made at 2 meters above ground level in ventilated shelters. These large-scale climatic averages are known as the *macroclimate*.

We can define smaller scales of climatic characterization—the *mesoscale* and the *microscale*. The mesoscale has horizontal dimensions on the order of ten's of miles. The microscale is much smaller—usually a few hundred feet or less horizontally and ten's of feet vertically. This organization of climates forms a nested structure in which the climate of the smaller scale is a modification of the climate of the larger; that is, smaller-scale climates are deviations from the mean climate of the larger area. These modifications are primarily due to deviations of the "surface" from the mean "surface," which is a combination of soil, plant cover, blacktop, rooftops, etc.

As we go to smaller and smaller scales, we find that wind, temperature, and balances of radiation (solar and infrared) undergo increasingly larger changes due to changes in the physical structure of the surface. Trees, being surface features, will have their largest effect at smaller scales.

### Energy Flow

The exchange of energy between a surface or an object (either can be considered a "system") and its environment is of central importance in understanding the controls of climate and microclimate of an area. Climatologists and meteorologists usually attack this problem by use of an energy budget model of the system under study. Energy flows into the system are considered positive, and those out as negative.

For example, during daylight hours, systems in the sun absorb radiant energy. This energy is converted to sensible heat, and the system increases in temperature. Generally, the temperature of the system rises above the temperature of its environment, and heat then flows from the system to the air by convection and to any solid in contact with the system by conduction. If the system has a wet surface, energy is consumed by evaporation. There is also an infrared radiant-energy exchange between the system and its surroundings.

In every case, heat flows down temperature gradients from high to lower. Sometimes, as at night, radiational cooling causes the temperature of a system to drop below that of its surroundings; and some, or perhaps all, of the avenues of heat exchange reverse themselves and supply heat to the system.

The relationship between temperature and flows of heat within and between systems and their surroundings may be very complex. For instance, radiation frosts are the result of a combination of strong outgoing (negative) net infrared radiation along with low wind speeds. In this case, the high infrared-radiation exchange is due to clear skies, which are thermally cold relative to cloudy skies. Under these conditions, the temperature of a bare soil surface drops rapidly because heat is removed by radiation and because the still air brings little heat by convection. The

only source of heat is that brought by conduction from deep soil layers to the surface. If the soil has low density, it will be a poor conductor of heat and will have low heat capacity, with little heat stored. Surface cooling will be faster than for a high-density soil.

Similar types of interactions occur in the energy budgets of plants, except that storage and conduction are less important than for soil, because most plant parts have far lower heat conductivity and heat capacity than soils. Human beings have energy budgets with an additional source of heat to consider: heat produced by metabolic activity. For energy budgets of buildings, temperature regulation by furnaces and air-conditioning must be considered.

## ROLES OF TREES IN METROPOLITAN CLIMATE

### Mesoscale Temperatures

Little work has been carried out to determine the effects of various kinds and amounts of city trees in moderating the climate of entire cities or metropolitan areas. Many comparisons between rural and urban temperatures have been made, but usually temperature differences have been ascribed only to differences between city structures and the surrounding generally vegetated areas. The amount and kind of vegetation in the non-city areas are not specified and are usually described only vaguely as part of a rural landscape.

Mesoscale temperature differences between city and country are frequently called "urban heat islands" because cities are usually warmer in both summer and winter. On summer nights, rural areas may be cooler than built-up areas by 10°F and occasionally even as much as 20°F *(Peterson 1969)*.

In one of the few studies of the distribution of urban surface materials *(Marotz and Coiner 1973)*, aerial photographs were used to charactize several cities in Kansas. The percentage of area covered by woody and other vegetation in cities of different size was determined (table 1). The authors suggest that the amount of vegetated surface within cities has been grossly underestimated. However, no temperature differences are given.

In an earlier experiment in mapping and modeling the effect of land use on urban thermal regimes *(Outcalt 1972)*, the term "urban cold doughnut" was coined. Thermophotography of farmland, a city center, new subdivisions, and old residential areas showed the existence of a daytime cold annulus (the doughnut) in the old residential neighborhoods about the city core. The cooler temperatures in the old neighborhoods were attributed to relatively wet but rough surfaces—mature transpiring trees.

Table 1.—Percentage of surface materials in some northeastern Kansas cities[1]

[From Marotz and Coiner 1973.]

| Material | Kansas City (pop. 168,213) | Lawrence (pop. 45,698) | Baldwin (pop. 2,520) | Eudora (pop. 2,071) | Tonganoxie (pop. 1,717) |
|---|---|---|---|---|---|
| Natural: | | | | | |
| Grass | 31 | 24 | 61 | 56 | 62 |
| Woody | 18 | 36 | 16 | 11 | 14 |
| Total | 53 | 63 | 85 | 72 | 79 |
| Modified | | | | | |
| Asphalt | 46 | 32 | 7 | 13 | 11 |
| Concrete | 1 | 2 | 1 | 2 | — |
| Gravel | 2 | 2 | 5 | 13 | 9 |
| Total | 51 | 39 | 15 | 28 | 21 |

[1] The method of sampling apparently yields approximate area percentage figures so that the totals "natural" and "modified" may equal more than 100 percent when added.

The suggestion that the urban cold doughnut is due to transpiring surfaces seems to enforce the frequently heard contention that trees are "nature's air conditioners" because of the large amounts of heat used in transpiring huge amounts of water. The results of a numerical modeling study of urban heat islands by Myrup *(1969)* also seem to indicate that transpirational cooling could be a very important role for urban trees. However, we don't really know how efficient "nature's air conditioners" are in city settings. High transpiration rates require adequate water supplies, but we do not really know much about the soil moisture conditions in urban areas and the resulting moisture status of trees.

### Use of Trees for Improving Human Thermal Comfort

At the microscale, trees have a very direct influence on thermal comfort of people. Thermal comfort is a physical condition resulting from the interaction of the human body with its thermal environment, which includes the variables: air temperature, relative humidity, wind speed, solar radiation, and infrared radiation. Trees can play a direct role by modifying some of these variables.

A human being is subject to the same flows of energy as a soil surface. The major difference is that whereas the soil is a passive system, the human provides a system that takes various actions to control its energy budget so as to maintain the sum of inputs and outputs of energy at zero. In fact, if the energy budget is not zero, the body is becoming warmer or cooler; and the human system cannot tolerate much change in deep body temperature without serious consequences.

Investigations of microclimate and human thermal comfort under way in Syracuse, N.Y., for several years *(Herrington and others 1972; Plumley 1975; Vittum 1974)* have yielded extensive data about the role of trees in moderating the human thermal environment. One of the most revealing results of these studies was that trees have no measurable effect on air temperature or humidity at the microscale. Within an area of several square blocks, there was no measurable change in air temperature and humidity regardless of the structure of sites or streets or the presence or absence of trees. Therefore we can eliminate any consideration of the effects of trees on air temperature or humidity at the microscale. The other variables of human comfort are subject to control by trees and other vegetation.

*Warm conditions.* — Vittum *(1974)* showed that solar radiation is probably the most important controllable microclimatic variable in relation to human comfort. Trees can be used to screen people and surfaces from direct solar radiation. Under different environmental conditions and for different people engaged in different activities, the amount of shade required for comfort will be different *(Plumley 1975)*. Therefore we need a variety of canopy densities available to site designers. The shading of building and street surfaces has a significant effect, under some conditions, on the infrared exchange between people and these surfaces: the cooler shaded surfaces supply less heat to people.

Trees and other vegetation can also be used to screen hot surfaces from the view of people and thus reduce the infrared radiation load on them by interception of the infrared stream. This works because, if there is any significant wind, leaves of trees are at or only slightly warmer than air temperature *(Knoerr 1967)*, and the infrared radiation from the leaves will be less than that from hot walls. For shading walls and for screening people from infrared radiation sources, trees with columnar-shaped relatively dense crowns are generally best.

*Cold conditions.*—Under cold-weather conditions, wind is the most important variable for human thermal comfort and safety. Designers could make considerably greater use of trees for wind reduction in many urban situations. The

extensive literature on windbreaks and shelterbelts *(see Holaday 1973 and Robinette 1972 for sources)* can be used as design guides and to determine characteristics of trees desirable in urban areas. Trees for windbreak purposes should usually be evergreen, although low-branching deciduous trees do significantly reduce wind speed; and windbreaks should be partially permeable for most applications.

It is convenient that deciduous trees, which are generally best for shading, lose their leaves in winter and allow passage of much solar radiation to warm people, streets, and walls in winter. However, more solar radiation is absorbed by leafless deciduous trees than is usually realized. Measurements in forests have shown that as much as 74 percent of incoming solar radiation may be absorbed by leafless trees *(Geiger 1965)*.

### Trees for Modfiying Building Energy Consumption

Trees can alter the physical energy budget of buildings by influencing air movement, radiation exchange, and air temperature. In popular literature there is frequent mention of the effect that trees have on home energy (fuel) consumption. Unfortunately, little quantitative information is available. We usually read statements indicating only that it is "good" to have trees around houses because fuel bills are lower. Sometimes, "by as much as 40 percent" is used; because a 1945 report *(Bates 1945b)* predicted that fuel savings of 40 percent were possible in the shelterbelt states, with "all-around protection in the center of a grove or forest."

*Trees as windbreaks.*—Wind can alter building energy budgets to a considerable extent. Formal studies of the windbreak effect of trees on fuel consumption for heating buildings were carried out at least 60 years ago *(Bates 1911)*, but we believe that no such studies were completed in the East until very recently *(Mattingly and Peters 1975)*. The general conclusion is that trees do serve effectively to achieve significant reductions in energy consumption.

Wind influences the physical energy budget of buildings through the process of convection of heat away from or to the exterior walls and by causing infiltration of outside air. For townhouses in a planned unit development in New Jersey, it was estimated that approximately one-third of the heat loss in winter was by conduction through exterior walls *(Fox 1973)*. Part of this conducted heat would then be transferred to outside air by convection and the rest emitted from the walls by longwave radiation. Infiltration of outside air through cracks around windows and doors accounted for roughly another one-third of the heat loss.

Air infiltration can also occur through pores in the material of walls *(Georgii 1953)*. Infiltration seems to be only slightly dependent on the difference in temperature between the inside and outside of buildings, but is strongly dependent on wind speed *(Georgii 1953, Mattingly and Peters 1975)*.

Studies of the effect of Great Plains shelterbelts on house heating pertain to relatively wide belts of deciduous trees. *Bates (1945a, 1945b)* used two test "houses" which were about 4 feet on each side. Shelterbelts were simulated by fences of vertical wooden slats. Wind information from actual shelterbelts was used to calculate a 25-percent saving of fuel for a house sheltered on the north side by a 10-row deciduous windbreak. For small yards in towns, "a compact mass of evergreens" close to the house was recommended by Bates, but he presented no calculations of fuel saving.

In wind-tunnel tests, Woodruff *(1954)* found that a 10-row defoliated shelterbelt would provide a 15-percent saving in heating costs for a house located two tree heights south of the belt. An average wind of 10 mph was assumed; other climatic conditions were those of Topeka, Kansas.

Mattingly and Peters *(1975)* did wind-

tunnel studies to model air-infiltration rates for the previously mentioned town houses in the planned unit development of Twin Rivers, N.J. A single row of trees was modelled by mounting triangular-shaped wire screens on vertical metal shafts. Visual density approximated that of a single row of white pine *(Pinus strobus)* or Norway spruce *(Picea abies)* trees. Tree models were equal in height to house height. Potential reduction of infiltration by trees was as much as 60 percent. Because infiltration was estimated to cause one-third of winter heat loss, the reduction in infiltration by a single row of tall conifers could mean a 20-percent reduction in fuel use at certain times. The average reduction for the entire season would not be as great.

Flemer *(1974)* compared fuel consumption in the same eastern house before and after an evergreen windbreak was installed. When the trees reached the height of the house, a fuel saving of 10 percent per winter over the former exposed condition was recorded.

*Trees for summer shade.*—We know of only one study that provides quantitative information about the effect of tree shade on temperatures within buildings. Working in California, Deering *(1956)* found that dense shade from trees might reduce maximum temperatures in houses by 20°F. He used a 20- by 8-foot house trailer to simulate a typical low-cost frame house. Construction included 2- by 3-inch studs with white clapboard siding and an asphalt-shingled roof. Data from 3 days with similar conditions of wind and ambient air temperature were used to compare temperature regimes inside the trailer for three different shade conditions.

When the trailer was beneath a group of large fig trees that provided shade all day, the temperature inside the trailer remained over 75°F only 5 hours in comparison to 11½ hours in full sun. Maximum temperature inside the trailer was 84°F in the shade, and 104°F in full sun. Shade of eucalyptus provided results similar to those for the fig shade, but direct comparison was not possible because the trailer was situated beside rather than within the eucalyptus grove, and no shade was provided in the morning.

## CONCLUSIONS

Some literature about the ability of trees to modify climate exhibits a degree of sensationalism. Thus a knowledge of basic principles of energy flows that control climate in metropolitan areas is important for realistic selection of trees for metropolitan use.

Control of radiation, particularly solar radiation, is probably the most important use of trees for controlling microclimate in urban areas. However, existing knowledge does not permit us to say much more than the obvious about using and selecting trees for control of solar radiation. Designers need a number of tree species with different solar-radiation-transmission characteristics to fit varied metropolitan environments. Deciduous species are preferable in temperate regions. Around new construction, fast-growing species that provide at least moderately dense shade are desirable. The albedo (reflectivity of solar radiation) does not vary sufficiently among species to warrant selection for climate control on this basis.

We can provide examples of species for use in the temperate climates of the eastern United States. Tall trees with normally wide-spreading, medium-dense crowns and high decurrent branching such as London plane *(Platanus* x *acerifolia)* or American elm *(Ulmus americana)* are usually most useful for yard or street shade trees. Low branching not only prevents shading of buildings, but also obstructs air flow in summer. The new "Urban elm", a cross between *Ulmus* x *hollandica* '*Vegeta*' and *Ulmus carpinifolia (Agricultural Research 1975)*, probably will not be as useful for moderating urban climate because of its low branch-

ng. More desirable from the standpoint of urban climate modification would be a revival of *Ulmus americana*. Thornless honeylocust *(Gleditsia triacanthos f. inermis)* has too thin a crown and is too short at maturity to provide sufficient shade for most urban sites.

Where windbreaks are desirable to reduce strong winter winds, several rows of low-branching deciduous species such as Lombardy poplar *(Populus nigra 'Italica')* or one of the columnar-shaped elms new being developed *(Agricultural Research 1975)* would be somewhat effective. However, evergreens would be generally more effective. We have no conclusive information for recommending particular evergreens as windbreaks.

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# TREES AND FORESTS FOR NOISE ABATEMENT AND VISUAL SCREENING

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*ABSTRACT.* Noise pollution is common in metropolitan areas, comes from many sources, and is a problem in human comfort and health. Noise measurement and the physics of noise propagation and reduction are complicated. Mechanisms of noise attenuation by forests are discussed, as well as the amount of reduction produced by various planting. Plantings are more effective as visual screens than as reducers of noise. Plantings occupying relatively narrow strips of land can fully serve screening purposes, whereas plantings usually must be at least 100 feet wide to be significantly effective for noise control. Because of insufficient data, recommendations on species composition desirable for either purpose are vague.

COMPLEMENTARY USES of trees for noise abatement and visual screening are often possible in metropolitan areas. Many sounds are not objectionable if the source cannot be seen. Also, visual screens are sometimes sufficiently dense and wide so that they create a real and significant reduction in noise. Hence, it is entirely appropriate to consider sound-abatement properties along with the screening properties of trees.

Excessive noise from highway traffic, industry, construction equipment, air-conditioning units, power mowers, and other appliances typical of our civilized metropolitan environment has resulted in strong complaints from residents—particularly home owners and apartment dwellers. Excessive noise interferes with communication by speech or telephone, sleep, and enjoyment of radio, records, and television. Excessive noise levels can cause psychological disorders and permanent hearing loss.

For these reasons, attempts have been

made to limit levels of noise emission in communities by federal, state, and local legislation. In all cases, this legislation involves compromises between economics, technical practicality, and personal annoyance. As with all compromises, none of the parties involved are fully satisfied, and some of the legislation is virtually unenforceable. Therefore, additional means of noise reduction, including the use of vegetative barriers, are being studied and applied to improve the metropolitan environment.

Metropolitan scenery frequently abounds in unsightly views that people find depressing—dilapidated buildings, refineries and factories, parking lots, storage yards, and the like. Trees can do much to improve views. Even a single row of shade trees along the side of a street will block much of the unsightliness of nearby buildings; and a single row of dense-foliage trees can often block more distant scenes of storage yards, factory parking lots, and in some places the factories and refineries themselves. In addition, tree barriers may be used to emphasize extraordinary pleasant views by blocking out those that are merely commonplace.

This paper summarizes the state of the art on using trees for noise reduction and visual screening, and discusses some aspects of selecting trees for these purposes. A brief review of noise sources, measures, propagation, and community reaction to noise is included.

## NOISE SOURCES, PROPAGATION, MEASUREMENT, AND HUMAN REACTION

Noise levels from such sources as automobiles, motorcycles, trucks, industrial plants, and most other community noise sources may be expressed in a number of ways. For our purposes, we will describe briefly only the four most common measures of noise. For those interested in a detailed discussion of acoustical measurements, Beranek *(1971)* is one of several good references.

Essentially all measurements of noise make use of the decibel (abbreviated dB) system. Decibel measurements are used for convenience where a large range of values must be compared. In general, decibel values are proportional to the logarithm of the ratio of a measured value divided by a reference level. In acoustics, the ratio is usually a sound pressure divided by a reference pressure of 0.0002 microbars. A line chart (fig. 1) may be used to add two decibel values. Note that if one sound source is placed beside another of equal intensity, the increase in sound pressure level will be only 3dB, regardless of the sound levels of the two equal sources.

One means of representing a noise source is to show the sound spectral content; that is, the noise amplitude distribution as a function of frequency at one time or averaged over a given time period. Typical octave band spectra for transportation and air-conditioner noises

Figure 1.—Line chart for the addition of sound-pressure levels.

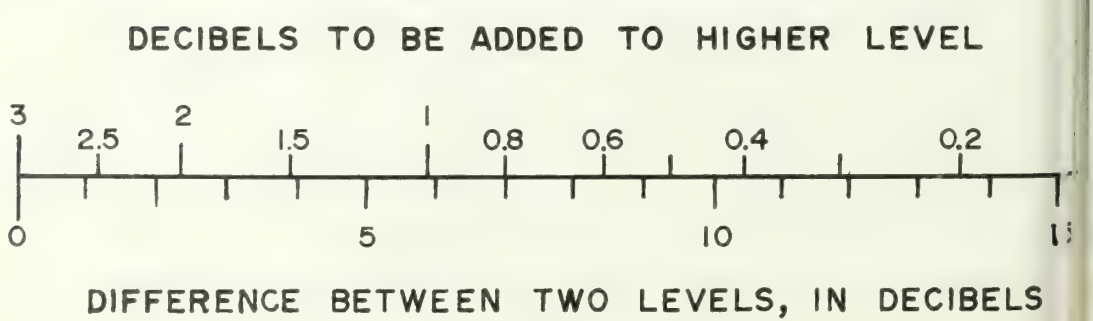
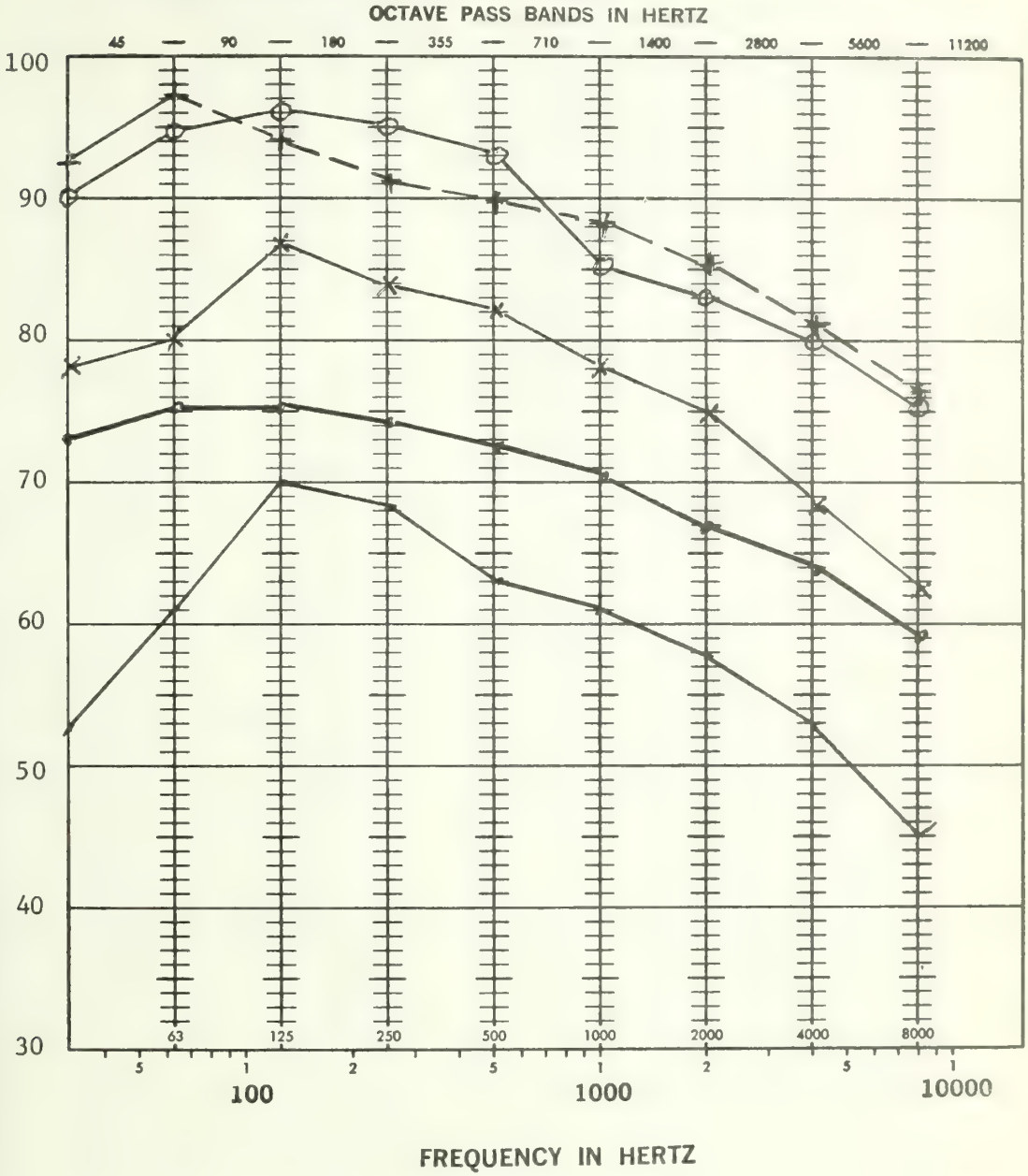


Figure 2.—Typical octave-band sound-pressure levels for noise from several transportation vehicles and an air-conditioner.




——— Air Conditioner

o——o Motorcycle at 50 feet

x——x Trucks at level cruise at 50 feet

•——• Passenger cars at 55 mph. at 50 feet

+ -- + 3000 HP Locomotive at 50 feet

are given in figure 2. The variation from these average values can be expected to be as much as 10dB. Community noises in general have a fairly broad spectrum.

The human ear does not react equally to all frequencies of sound, and the so-called "A" weighting characteristic is used to adjust sound-pressure levels to obtain a measure called dBA, which approximates the loudness of sounds as they are perceived by humans. The range of frequencies the typical young adult can hear is from about 20 to 15,000 Hz (Hertz, cycles per second). However, our hearing is most acute in the 1,000 to 4,000 Hz range. Table 1 shows how sound-pressure levels given in octave bands are adjusted for A-weighting. Typical sound-pressure levels in dBA for various sources are given in table 2.

A third means of describing noise is by Speech Interference Level ($L_{SI}$), which is obtained by calculating the arithmetic average of the 500-, 1,000-, and 2,000-Hz octave-band sound-pressure levels. Speech communication is one of the most important human activities. For particular indoor environments, the permissible noise in terms of $L_{SI}$ values ranges from 35dB (42dBA) for homes to 45dB (52dBA) for private offices to 60dB (67dBA) for secretarial areas. Thus, most of the noise from transportation, construction equipment, and manufacturing plants will interfere with speech communication at the distances from the sources listed in table 2.

Another widely-accepted evaluation of community noise is the Noise Pollution Level ($L_{NP}$). It provides a measure of statistical variation with time of noise levels measured in dBA. In terms of community reaction, the U.S. Department of Housing and Urban Development has established the outside Noise Pollution Level criteria given in table 3.

In using these measures of community noise, remember that the hearing acuity of human beings varies substantially from one person to the next. People respond differently to noise based on background,

**Table 1.—Corrections for A-weighted octave band analysis**

| Band center frequency | A-weighting correction |
|---|---|
| *Hz* | *dB* |
| 31.5 | −39.4 |
| 63 | −26.2 |
| 125 | −16.1 |
| 250 | − 8.6 |
| 500 | − 3.2 |
| 1,000 | 0 |
| 2,000 | + 1.2 |
| 4,000 | + 1.0 |
| 8,000 | − 1.1 |

**Table 2.—Sound-pressure levels of typical noise sources**

| Source | Sound-pressure level range | Distance |
|---|---|---|
| | *dBA* | *Feet* |
| Whisper | 25-40 | 5 |
| Residential area at night | 35-45 | |
| Large transformer | 48-55 | 200 |
| Automobile: | | |
| < 35 mph | 62-72 | 25 |
| > 35 mph | 70-78 | 25 |
| Accelerating | 82-88 | |
| Truck with muffler: | | |
| < 35 mph | 74-78 | 50 |
| > 35 mph | 80-85 | 50 |
| Accelerating | 82-90 | 50 |
| up 4% grade | 85-88 | 50 |
| Truck without muffler up 4% grade | 93-100 | 50 |
| Motorcycles: | | |
| < 35 mph | 75-83 | 20 |
| Accelerating | 90-97 | 25 |
| Earthmoving scraper | 80-92 | 50 |
| Concrete mixer | 75-88 | 50 |
| Pile driver | 95-105 | 50 |
| Air compressor | 75-85 | 50 |
| Rock drill | 81-98 | 50 |
| Lawnmower | 68 | 50 |
| Freight train 3,000-hp diesel, 30-40 mph | 85-95 | 100 |
| High-speed turbo train | 100 | 100 |
| Can-manufacturing plant | 52-65 | — |
| Oil refinery | 51-68 | — |

Sources: Lyon 1973, EPA 1971a and 1971b, NASA 1970.

**Table 3.—Community noise criteria based on noise-pollution level**

| Criteria | Noise level |
|---|---|
| Clearly acceptable | < 62dB ($L_{NP}$) |
| Normally acceptable | 62 < 74dB ($L_{NP}$) |
| Normally unacceptable | 74 < 88dB ($L_{NP}$) |
| Clearly unacceptable | > 88dB ($L_{NP}$) |

prior exposure, interests, and various physiological factors. In addition to the level of noise, the existence of pure tones, impulsive sounds, duration of noise, and time of day or night also affect community reaction to noise.

Some precautions need to be taken in interpreting sound measurements and attenuation. For example, a pure-tone sound travelling over a flat hard surface will result in destructive wave interference between the direct wave at a particular location and the reflected wave that, since it travels a longer distance, may be out of phase with the direct wave. Thus, measurement at one location may indicate a very high attenuation that would not be recorded at a slightly different location. This phenomenon may also occur to a somewhat lesser degree over porous ground. On the other hand, at another location the relative phase relationship between direct and ground-reflected waves may be such that augmentation takes place, resulting in a sound increase or negative noise reduction.

A second example occurs in thermal inversions on clear nights when there may be significant noise increases at particular locations as the "sound ray" actually bends down toward the earth near the receiver location. The speed of sound is proportional to the square root of the absolute temperature of the air, so an increasing air temperature with increasing height above the ground will cause this phenomenon. In midday, when radiation from the sun heats the air near the ground, the opposite phenomenon occurs, and actual "shadow zones" are generated where less sound is heard.

## SHRUBS, TREES AND FORESTS FOR NOISE ABATEMENT

The use of trees, shrubs, and various ground covers for the purpose of attenuating the noise from highways and industries has been under study for the last 5 years. The intent of these studies was to establish the so-called "excess attenuation" achieved by the intervening "noise barrier". This excess attenuation is the noise reduction obtained from the attenuation means adjusted for the spherical spreading of sound in a free field and the absorption of sound by the atmosphere.

The processes that result in the attenuation by forests are quite complicated. Consider a forest having a floor of decayed material, grasses, some sand, and rock. There are some deciduous shrubs and a variety of deciduous and coniferous trees up to 60 feet tall, having trunks up to 2 feet in diameter. As the sound wave approaches the forest edge, the ground cover will absorb some of the sound in grazing incidence. The very low frequencies (20-100Hz) will either pass right through the forest or be absorbed by the ground. The high frequencies (2,000 to 8,000Hz) will be reflected and diffracted by the larger trunks and branches, resulting in multiple scattering and some absorption. Recent tests in The Pennsylvania State University Noise Control Laboratory show that even the thickest barks on large trunks are very poor acoustic absorbers. On the other hand, typical forest floors of either decaying leaves or needles are excellent acoustic absorbers over a fairly wide range of frequencies. Generally speaking, the denser the forest, the better the absorption.

Several researchers *(Embleton 1963, Eyring 1946, Reethof 1973, Wiener and Keast 1959)* have made tests in extensive moderately dense forests where visibility was between 100 and 200 feet. Their results show that the excess attenuation per 100 feet of depth, as a function of octave band frequencies, is very modest at the important low frequencies and becomes very significant at the high frequencies (fig. 3). On the other hand, the weighting correction is quite large at low frequencies. Thus, a 200-foot-deep forest typical of the northeastern United States would result in the reduction of typical locomotive noise as shown in table 4 (which also indicates the various steps in

Figure 3.—Sound attenuation by forests (Reethof 1973).

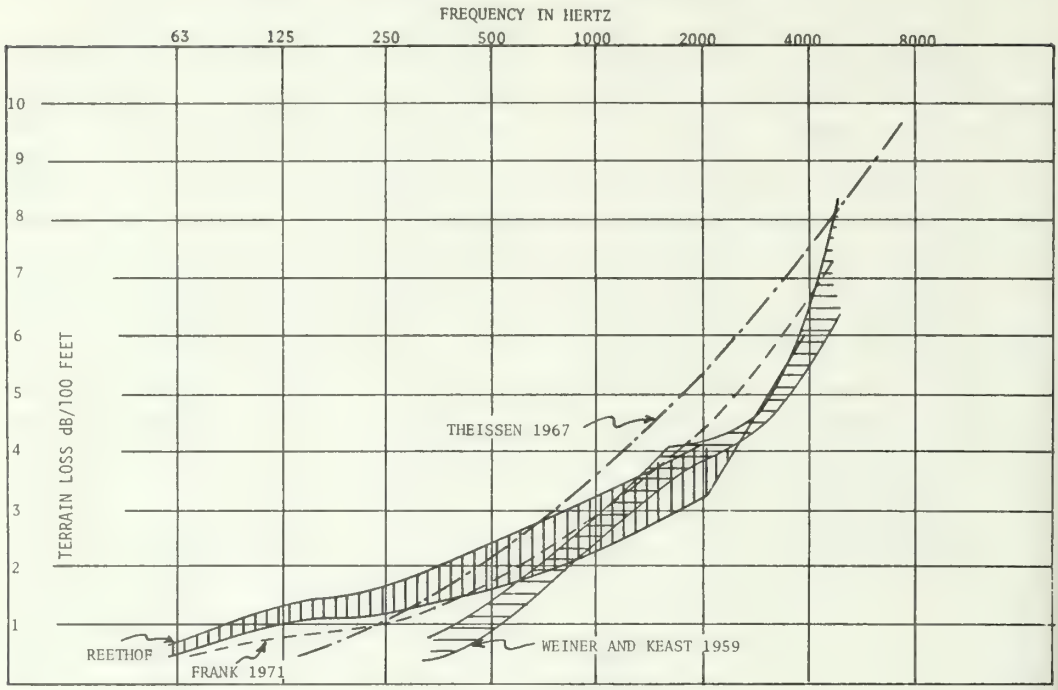



Table 4.—Locomotive noise attenuation with and without a 200-foot-deep forest

| Octave band center frequency | Locomotive noise at 50 feet | Spherical spreading for 200 feet | Excess attenuation by forest | "A" correction | "A" correction of unattenuated locomotive noise at 50 feet | Locomotive noise at 250 feet without forest | Locomotive noise at 250 feet with forest |
|---|---|---|---|---|---|---|---|
| *Hz* | *db* | *dB* | *dB* | *db* | *db* | *dB* | *dB* |
| 31.5 | 92 | 14 | 0 | −39 | 53 | 39 | 39 |
| 63 | 97 | 14 | 1 | −26 | 71 | 57 | 56 |
| 125 | 93 | 14 | 2 | −16 | 77 | 63 | 61 |
| 250 | 91 | 14 | 3 | −9 | 82 | 68 | 65 |
| 500 | 90 | 14 | 4 | −3 | 87 | 73 | 69 |
| 1,000 | 88 | 14 | 6 | 0 | 88 | 74 | 68 |
| 2,000 | 85 | 14 | 8 | +1 | 86 | 72 | 64 |
| 4,000 | 81 | 14 | 12 | +1 | 82 | 68 | 56 |
| 8,000 | 76 | 14 | 20 | −1 | 75 | 61 | 41 |
| Total | 101 | — | — | — | 93dBA | 79dBA | 73dBA |

the calculation). The locomotive noise at 50 feet has an A-weighted level of 93dBA, whereas the locomotive noise reduced by spherical spreading from 50 to 250 feet and attenuated by the forest is reduced to 73dBA. Without the forest effect, the level of 50 feet is 79dBA. This example indicates that 200 feet of forest may provide an important reduction in transportation noise.

Work done by Whitcomb and Stowers *(1973)* in Florida shows that hedges also provide significant reduction in noise from lawnmowers and traffic. They tested

a broad-leafed dense hedge *(Illicium anisatum)* 5 feet thick and 8 feet high, using a source and a receiver located close to the hedge. A 5dB reduction in A-weighted level was obtanied when source and receiver were located about 13 feet apart, each being about 4 feet from the hedge and at a height of 3 feet above the ground. Whitcomb and Stowers showed that leaf size, shape and density were of prime importance in modifying the amount of noise reduction. Aylor *(1972a, 1972b)* studied various types of high-density ground covers and again showed the importance of leaf density and leaf size, and the effect of frequency on excess attenuation.

Cook and Van Haverbeke *(1971)* found that 65- to 100-foot-wide belts of trees and shrubs can be effective barriers of noise from high-speed traffic if the near edge of the belt is within 80 feet of the nearest traffic. The approach to the barrier should have soft ground and a grass cover, and not be in hard paved surfaces. To increase the effectivenes of plantings, 8 to 10 feet high, 50- to 100-foot-wide earth landforms should be constructed and should be planted with dense shrubs on the highway side *(Cook and Van Haverbeke 1974)*. A strip at least 20 feet wide beyond the shrubs should be planted with coniferous and deciduous trees that will grow tall in time. Excess attenuations of about 10dB of typical traffic noise can be expected from the tree and landform combinations.

## TREES FOR VISUAL SCREENING

### Architectural Basis

Many architectual uses of trees involve visual screening of some kind. Robinette *(1972)* uses the term "screening" to refer specifically to "view blockage" or the hiding of objectionable objects or scenes from view. In reality, however, many other architectual uses for trees include their use as barriers or screens. Such other uses are space definition or articulation (room-making), privacy control, and "progressive realization". Robinette defines progressive realization as "enticement and tantalization", the gradual opening to view of a special scene by showing a small glimpse, then more of the scene, and eventually the whole picture. There are numerous other ways that skilled landscape architects make use of tree barriers for guiding the movement of people through spaces, for guiding their eyes to objects or parts of buildings that are to be emphasized, and for creating particular optical impressions. References are available that describe techniques for using trees for screening and barriers *(Lynch 1971, Simonds 1961, Robinette 1972)*.

### Species Selection

There seems to be a definite lack of information about when and how to use particular plant materials for screening. Some landscape planners have learned much about the use of different plant species for screening in their own local areas. However, Robinette *(1972)* indicated that available information about the effectiveness of plants as screening elements "has not been well catalogued and indexed". Although planting screens for highway beautification "gained wide acceptance in the mid 1960's, quantitative data was unavailable to show ways plants can be used to screen and what their limitations are". Even in the Great Plains, where shelterbelt planting has provided many years of experience in the establishment of tree barriers, only limited information on the use of trees for highway screening and beautification is available *(Davidson 1970)*.

In spite of some gaps in our ability to prescribe tree species for screening and barriers, some suggestions can be made. Evergreen coniferous species are usually best for year-round screening. The trees are often sheared to produce maximum density. Depending on the location, deciduous species are also valuable as visual screens. If the screen is to hide a view that is objectionable only in sum-

mer, deciduous species obviously have a place and might be preferable because of faster growth. Further, visual screens need not always be essentially opaque to be effective. Particularly if the observer is moving, a partially open screen may be just as effective as a wall of vegetation, and a hemmed-in feeling may be avoided. In some situations an eye-catcher such as a lone clump of white-barked birches or other specimen tree may distract people from views that are best unseen.

*Living Screens for America*, a booklet recently published by the American Association of Nurserymen, provides a list of species that have screening potential. This booklet is a good start in the effort to catalog species for screening purposes. Suggestions are based on plant hardiness, rapidity of growth, availability, disease resistance, low maintenance, and reasonable cost.

Sufficient diversity of useful plant materials to provide variation in design is one requirement for successful landscape planning. In many metropolitan residential areas, adequate diversity probably already exists. For example, in the heart of the eastern megalopolis are vast areas that serve as bedroom communities for New York, Philadelphia, Baltimore, and Washington. These exurban areas (outside the suburbs, containing plentiful open space and with primarily single-family dwellings) can easily be classed as metropolitan even though they are as much as an hour travel by fast train or bus from truly urban areas.

Central New Jersey has many exurban landscapes. Here, where stresses that must be endured by plants in large cities are generally reduced, plant materials for barriers are in good supply and are adequately diverse in characteristics. The species which Robinette *(1972)* lists as some of the most visually dense are easily grown for screens. In order of decreasing density these species include arbor-vitae *(Thuja occidentalis)*, eastern hemlock *(Tsuga canadensis)*, Douglas-fir *(Pseudotsuga menziesii)*, white spruce *(Picea glauca)*, and white pine *(Pinus strobus)*.

In many metropolitan residential communities, the selection of species for visual screening is more difficult. For example, in New England and upper New York State the variety of plants that can survive is somewhat reduced because of more severe winters. If air-pollution problems and highway salting are added to the list of stresses on plants, many coniferous species, which are so useful for visual screening, cannot be used. Selection and breeding of a greater variety of stress-resistant conifers for visual screening would be desirable.

In major urban areas, the need is still more critical. The list of useful coniferous species for visual screening is definitely limited, and we need more variety in deciduous species that can withstand urban stresses. Often the urban view most in need of screening is directly overhead. The thin lacy foliage of thornless honeylocust *(Gleditsia triacanthos f. inermis)* forms a pleasant over-head veil; but sometimes a dense canopy is called for. Some *Ginkgo biloba* clones form a solid canopy, but others are little better than honeylocust. London planes may suffice, but often even their canopies are not sufficiently dense, particularly in cities.

Coal-mine spoil banks are definitely detrimental to both the economy and the esthetic quality of some highly populated regions. Guides for selecting species to screen coal-mine spoils in northeastern Pennsylvania are available *(Frank 1964 Czapowskyj and McQuilkin 1966)*. To hide these spoils, Frank recommended planting about a million trees in multirow screens: slow-growing evergreens that retain their branches, such as spruces, in the front; faster-growing evergreens, such as pines, in the center; and still faster growing deciduous species, such as black locust or larch, in the back. His recommended width of screen was 100 feet, a width that would also reduce the noise of highway traffic according to many authors.

For screening and beautification of highways in the Great Plains, Davidson *(1970)* listed 16 tree species and 13 shrub species, described their hardiness and site requirements, and discussed in general terms their screening abilities.

## CONCLUSIONS

Dense and tall ground cover and particularly dense and extensive plantings of trees and shrubs can be used effectively to reduce transportation and industrial noise. Low frequencies, typical of low-speed truck noise, are attenuated to a far lesser degree than the higher frequencies characteristic of high-speed traffic and industrial noise sources. However, low-frequency truck noise is in a frequency range in which the human ear is quite insensitive to sound. A thick litter layer is an important element in the sound absorption process of forests.

Mature forests, whether coniferous, deciduous, or mixed, attenuate noise similarly over the audible frequency range. Natural forests should be 200 to 500 feet wide to provide significant noise reduction from traffic noise; but planted barriers of shrubs and a mixture of coniferous and deciduous trees can be made denser than most natural forests, and the width of the barrier may be less—100 to 200 feet. A few studies have indicated that dense tree or hedge barriers, only 20 feet or even less in width, are effective. However, other studies showed no significant attenuation from such narrow vegetative barriers. It is generally agreed that narrow belts of vegetation are psychologically effective by screening noise sources from view. Tree barriers on raised landforms, 15 to 30 feet higher than the source and the receiver, are more effective than either trees or landforms alone.

There are a number of applications for trees as visual barriers beside the obvious purpose of hiding an unpleasant scene from view. Although evergreen conifers are generally the most desirable for visual-barrier plantings, faster growth may make deciduous species the best choice for barriers where some visual permeability is acceptable in winter or where space is available for a wide barrier. Deciduous species may also be used in a parallel combination with evergreens to add variety to a screen.

Some studies indicate that leaf sizes and shapes are important variables in the ability of trees to attenuate noise. However, other studies have shown that leaf size and shape are unimportant. Selection of trees for noise barriers should be based on the ability of the species for survival and rapid growth of a dense tree barrier. Fast-growing, shade-tolerant species would usually be most suitable. For visual screening, there is a definite need for selection and breeding of trees to provide a greater variety of species—especially conifers—that can withstand urban stresses.

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# CAPABILITY OF METROPOLITAN TREES TO REDUCE ATMOSPHERIC CONTAMINANTS

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*ABSTRACT.* The most damaging levels of air pollution are reached in industrial and urban areas. Atmospheric contaminants in metropolitan areas include both particulate and gaseous pollutants. Since trees have evolved in the presence of numerous materials presently considered air pollutants, and since trees are frequently abundant in urban areas, it has been speculated that trees may function as effective sinks for trace contaminants. Mechanisms for removing particulate matter may include sedimentation onto tree surfaces, impaction on tree surfaces, and precipitation transfer to tree surfaces. Mechanisms for gaseous removal by trees may include uptake via plant pores and surface adsorption. Sufficient potential for this sink function is indicated to justify consideration of this amenity function in tree selection and breeding programs for metropolitan trees.

AIR POLLUTION is the phenomenon of atypical increase in trace contaminant levels of the atmosphere, resulting from the activities of man or extraordinary natural events such as volcanic eruptions, dust storms, or fires. The ramifications of numerous air pollutants are global in nature. Acute (high-dosage) effects of air contaminants, however, are generally regional or local phenomena associated with roadways, commercial and industrial facilities, or urban areas.

The air pollutants of significance to man and vegetation are varied; they include solid, liquid, and gaseous materials:

I. PARTICULATES:
  A. Solid (organic, inorganic)
    1. Nonviable
    2. Viable
  B. Liquid
II. GASES:
  A. Primary (released directly into the atmosphere)
    1. Inorganic
      a. Oxides
        i. Nitrogen
        ii. Sulfur
        iii. Carbon
      b. Halogens

i. Fluorine
ii. Chlorine
c. Other
i. Hydrogen sulfide
ii. Ammonia
2. Organic
a. Hydrocarbons
b. Aldehydes (ketones)
c. Mercaptans
B. Secondary (synthesized in the atmosphere)
a. Ozone
b. Peroxyacetylnitrate and homologues

Air-quality considerations in metropolitan areas are especially critical because of the tremendous aggregation of people and machines. In addition, urban regions cover impressively large areas. By the year 2000 the total urban-suburban land area may exceed 300 million acres *(Pickard 1971)*, with approximately 85 percent of us residing in urban communities. The emission trends of numerous air pollutants have been increasing in the recent past *(Cavender and others 1973)*; and the total national cost of air pollution, with much of this damage concentrated in urban areas, was estimated to be in excess of 16 billion dollars in 1968 *(Barrett and Waddell 1973)*. All strategies to reduce urban air pollution must be considered. One of the strategies may involve the ability of vegetation to remove air pollutants from the atmosphere.

Numerous particulate and gaseous materials classified as air pollutants have natural origins. Carbon monoxide, hydrogen sulfide, ammonia, oxides of nitrogen, and hydrocarbons derived from natural sources greatly exceed the emission of these gases from anthropogenic sources *(Robinson and Robbins 1968, Weinstock and Niki 1972)*. The annual global contribution of hydrocarbons by forests is $175 \times 10^6$ metric tons of reactive hydrocarbons from tree foliage. This is six times larger than the emission level from man-made sources *(Rasmussen 1972)*.

Components of ecosystems that remove pollutants from the atmospheric compartment and store, metabolize, or transfer them are termed "sinks" *(Warren 1973)*. Since plants have evolved in the presence of numerous compounds presently considered air pollutants, and since vegetation covers 90 percent of the land in the United States, it is reasonable to hypothesize that terrestrial ecosystems act as important sinks for air contaminants. Vegetative, soil, and water compartments of natural ecosystems may all be important sinks for numerous atmospheric contaminants. If plant tolerance is great enough, the sink function may extend to low pollution loads generated by man. This suggestion has been made by numerous investigators *(Dochinger 1975, Hanson and Thorne 1970, Lamanna 1970, Stewart and Wilken 1966, Waggoner 1971)*. Forest ecosystems have been suggested to be potentially important air-pollution sinks *(Smith 1974)*.

Evidence that soils may be particularly important sinks for numerous particulate and gaseous air contaminants is accumulating. In a recent review, Bohn *(1972)* indicated that while soils do emit some compounds considered air pollutants, they readily absorb numerous particulate and gaseous pollutants. He indicated that the amount of air pollutants absorbed by animal life is negligible and that most air pollution is absorbed by vegetation and soils.

In recent years many people have examined the specific capabilities of individual plants to remove contaminants from the atmosphere. Most of them have dealt with gaseous pollutants and nonwoody plant species. Some evidence to support the hypothesis that plants remove both particulate and gaseous pollutants from the atmosphere has been provided.

## PARTICULATES

### Characterization

Particulates are solid or liquid trace elements in the atmosphere. Their character is extremely varied; they may be

viable or nonviable, organic or inorganic. The inorganic fraction usually contains a few dozen elements, many metallic, the most common being silicon, calcium, aluminum, and iron. The organic fraction may contain a large number of aliphatic and aromatic hydrocarbons, aldehydes, ketones, and acids. Viable particles include pollen grains, fungal spores, and bacterial cells.

Particulates may range in size from approximately 0.0005 to 500 micrometers ($\mu$m) in diameter. Because of their large mass, large particles have a high rate of sedimentation and short longevity in the atmosphere. Small particles are usually electrically charged and frequently attach to other particles. Particles larger than 10 $\mu$m frequently result from mechanical processes: for example, wind erosion, grinding, or spraying. Many pollen grains and fungus spores are larger than 10 $\mu$m. Soil particles, process dust, industrial combustion products, and marine salt particles are typically between 1 and 10$\mu$m in diameter. Particles in the 0.1- to 1-$\mu$m range frequently represent gases that have condensed to form nonvolatile products. Lee *(1972)* has suggested that particulate matter suspended in urban air in the United States is predominantly less than 1 $\mu$m in size. Aerosols close to roadways are larger than those found some distance away because of reentrainment of debris by traffic-induced turbulence.

The annual mean concentrations of suspended particulate matter in United States urban areas range from 60$\mu$g/m$^3$ to 200$\mu$g/m$^3$. The maximum 24-hr average concentration is usually approximately three times the annual mean. Urban areas generally have higher particulate loads in the winter than in the summer *(Spirtas and Levin 1971)*.

### Mechanisms of Removal

Much of the understanding of the mechanics of deposition of particles on natural surfaces has been gleaned from studies with particles in the size range of 1 to 50$\mu$m and is reviewed in the papers of Chamberlain *(1967)* and Ingold *(1971)*. Basically particulates are deposited on natural surfaces by three processes: sedimentation under the influence of gravity, impaction under the influence of eddy currents, and deposition under the influence of precipitation.

Sedimentation usually results in the deposition of particles on the upper surfaces of plant parts and is most important with large particles. Sedimentation velocity varies with particle density, shape, and other factors. Impaction occurs when air flows past an obstacle and the airstream divides; but particles in the air tend to continue straight—due to their momentum—till they strike an obstacle. The efficiency of collection via impaction increases with decreasing diameter of the collecting obstacle and increasing diameter of the particle. Chamberlain *(1967)* suggested that impaction is the principal means of deposition if: (1) particle size is of the order of 10's of microns or greater, (2) obstacle size is of the order of centimeters or less; (3) approach velocity is of the order of meters per second or more; and (4) the collecting surface is wet, sticky, hairy, or otherwise retentive.

Ingold *(1971)* presented data indicating that leaf petioles are considerably more efficient particulate impactors than either the twigs (stems) or the leaf blade. Impaction is not efficient for particles of 1 to 5$\mu$m, and interception by fine hairs on vegetation is possibly the most efficient retentive mechanism. The efficiency of washout of particles by rain is high for particles approximately 20 to 30$\mu$m in size. The capturing efficiency of raindrops falls off very sharply for particles of 5$\mu$m or less. Particulate removal by stomatal uptake has been suggested *(Jordan 1975)*, but is of unclear significance. The latter process would probably involve small ($<1\mu$m diameter) particles.

### Vegetation as Particulate Sinks

Because of the considerable interest in the distribution of radioactive material

following the use of nuclear weapons or nuclear accidents, several investigators have examined the ability of aboveground plant parts to intercept radioactive aerosols *(Chamberlain 1970, Oak Ridge National Laboratory 1969)*. Dahlman and others *(1969)* examined the behaviour of $^{137}$Cs-tagged particles ($^{137}$Cs fused to 88-177$\mu$m silica sand) in a fescue meadow. Sand particles intercepted by grass blades were readily dislodged by light wind, and maximum retention time was approximately 10 days. If trapped in leaf axils, particles remained for longer periods.

Witherspoon and Taylor *(1971)* studied retention by soybean and sorghum plants, using smaller (average diameter 7.5$\mu$m, range 1 to 44$\mu$m) sand particles tagged with $^{134}$Cs. Initial interception of particles was similar, with values of 40 and 38 percent of the deposition quantity retained by soybeans and sorghum respectively. Over 80 percent of the soybean interception was by the foliage. The major site of sorghum interception, however, was the axil where the leaf joins the stalk and forms a sheath. Very rapid loss of particles occurred during the first week after deposition, soybean losing 79 percent and sorghum 88 percent of the particles.

In their study of common grasses (zoysia, bluegrass, fescue, and Bermuda) treated with $^{134}$Cs-sand particles (44-88$\mu$m dia), Peters and Witherspoon (1972) observed that initial interception varied between 68 and 82 percent. Weathering half-lives of particles on foliage averaged 4, 37, and 81 days, respectively, for the time periods of 0-3, 3-35 and 35-48 days after deposition. This suggested that grasses have relatively effective structures for particle retention.

Chadwick and Chamberlain *(1970)* observed that the loss of radionuclides from an old grassland in England was faster in summer than winter. Moorby and Squire (1963) documented the loss of radioactive particles from the leaves of several agricultural crops, even when the plants were protected from precipitation.

Other evidence for the ability of plants to trap atmospheric particulates comes from studies concerned with sodium and plant nutrient cycling in maritime ecosystems *(Martin 1959, Oosting and Billings 1942)*. Numerous studies have demonstrated that the effective surface for salt deposition is larger where plants are present than over bare ground. Clayton *(1972)* described the trapping of particulate salts by *Baccharis* brushlands in coastal California. Woodcock *(1953)* provided evidence that the shape of plant leaves influences the amount of salt deposited. By employing plates of various shapes, he found that long narrow plates accumulated more salt per unit area than did plate centers. Edwards and Claxton *(1964)* found over four times the deposition of salt on the windward side of a hedgerow compared to the leeward side.

Parallel studies of the retention of dust, sodium, nutrient, and radioactive particles by woody plants are also available *(Warren 1973)*. In addition, several studies have stressed the ability of trees to accumulate heavy metal particulates. In an Ohio study, Dochinger *(1972)* examined dustfall and suspended particulate matter in three areas; treeless, deciduous canopy, and conifer canopy; he concluded that trees have the capacity to reduce particulate pollutants in the atmosphere. Trees may be especially efficient filters of airborne particles because of their large size, high surface to volume ratio of foliage, and frequently hairy or rough leaf, twig, or bark surfaces.

Witherspoon and Taylor *(1969)* treated seedling white pine and red oak with 88 to 175$\mu$m diameter quartz particles tagged with $^{134}$Cs. Initial particle retention by oak foliage was 35 percent, by pine only 24 percent. After 1 hour, however, the oak leaves lost 91 percent of their initial concentrations while pines lost only 10 percent. Most pine particles were trapped at the base of needle bun-

dles around branch termini while oak particles were retained in small hairy recesses along leaf veins. Particle half-lives were calculated at intervals of 0 to 1 day, 1 to 7 days, and 7 to 33 days. For pine the values were 0.25, 5, and 21 days respectively. For oak they were 0.12, 1, and 25 days. Particulate loss was primarily attributed to the action of wind and rain. Zinke *(1967)* estimated that the retention of airborne materials ranged from 17 to 57 percent in pine stands and 82 to 86 percent in hardwood forests.

Numerous investigations, reviewed by White and Turner *(1970)*, have indicated that trees catch airborne nutrient particles. These authors found that their mixed deciduous forest was capable of annually removing 125 kg/ha sodium, 6 kg/ha potassium, 4 kg/ha calcium, 16 kg/ha magnesium, and 0.1 kg/ha phosphorus from the atmosphere. Degree of leaf hairiness was inversely correlated with particle retention. Apparently the small droplets employed had insufficient inertia to penetrate the stable boundary layer created by the hairy leaves. Small branches were more efficient particle collectors than large branches in all species examined.

Wedding and others *(1975)* found, under controlled wind tunnel conditions, that particulate deposition on rough pubescent sunflower leaves was 10 times greater than on smooth, waxy yellow-poplar leaves. They concluded that particulate retention could be quantitatively determined for plants existing in an environment of known aerosol concentration. Many investigators, for example Raynor and others *(1966)*, have shown that the concentration of particles carried by an air mass through a woodland decreases rapidly from the edge. Considerable rainfall interception data *(Helvey 1971)* indicate that canopy interception loss is greatest in the spruce-fir-hemlock type, intermediate in pine, and least in broad-leaved deciduous forests.

Trees located in industrial regions can become excessively contaminated with particulate emissions. Documentation from limestone operations *(Manning 1971)* and metal smelters *(Buchauer 1973, Little and Martin 1972)* is available. Rural, suburban, and urban roadside environments are also sites of excessive particulate subtraction by woody plants *(Smith 1975)*. Particularly abundant particulates include salt *(Smith 1970)* and heavy metals *(Heichel and Hankin 1972, Smith 1971, 1972, 1973)*. Smith *(1974)* estimated that the leaves and current twigs of a 30-cm (12-inch) diameter urban sugar maple remove from the atmosphere 60, 140, 5,800, and 820 mg of cadmium, chromium, lead, and nickel respectively during the course of a single growing season.

## GASES

### Characterization

The most significant gaseous contaminants of urban atmospheres are listed in table 1. Because of their abundance, human and vegetative health consequences and ability to deteriorate materials, the oxides of nitrogen, sulfur and carbon, hydrocarbons, and ozone are the most important.

### Mechanisms of Removal

The primary way vegetation removes gases from the atmosphere is by uptake through the stomates. Minor methods by which plants remove gaseous pollutants from the atmosphere may include uptake by plant surface microflora, uptake through bark pores, and adsorption of gases to the surface of plant parts.

The processes of transpiration and photosynthesis require that plants exchange gases with the ambient atmosphere through leaf, branch, and stem pores. Contaminant gases present in the atmosphere in the vicinity of a plant may be absorbed when the stomates or lenticels are open.

Spedding *(1969)* investigated the uptake of $SO_2$ by barley leaves and found a 6-fold increase in average deposition ve-

locity with open stomata compared to closed ones. In related work, Rich and associates *(1970)* reported that uptake of $0_3$ by bean was regulated by the same factors that control the exchange of water vapor between leaves and the atmosphere. This conclusion is also supported by Thorne and Hanson *(1972)*. Once inside the leaf, gases probably become dissolved in water. Hill *(1971)* compared the rates of uptake of pollutants by alfalfa with the water solubility of the pollutants. Fluorides had the highest water solubility and uptake. As the rates of uptake of pollutants decreased, their water solubility was also reduced. Any factor that affects the stomata influences the uptake rate of gaseous pollutants. Some of the environmental factors that are important in the action of stomata are light, humidity, temperature, wind, and the available supply of soil water.

Atmospheric pollutants themselves are also reported to have an effect on stomatal activity. Majernik and Mansfield *(1970)* and Unsworth and others *(1972)* reported that $SO_2$ caused stomata to open faster in the light, to achieve a greater aperature, and to close more slowly in darkness. All of these would allow for the absorption of more $SO_2$.

Guderian *(1970)* reported that the concentration of the pollutant in the air affected the sorption of the pollutant. He found that sulfur was sorbed least when the concentration was the highest and that the sorption of $SO_2$ increased with decreasing atmospheric concentration of $SO_2$ and increased exposure time. Brennan and associates *(1964)* reported somewhat different results. They found that the sulfur content of leaves increased as the $SO_2$ concentration increased during 4-hour fumigation periods. The sulfur content of leaves injured by high concentrations of $SO_2$ exceeded 0.30 percent. The sulfur content of leaves exposed to lower concentrations of $SO_2$ for longer periods of time was equally high, but no injury was noted.

Martin and Barber *(1971)* measured loss of atmospheric $SO_2$ over a hawthorn hedge. Maximum foliar intake was through foliar absorption during the warm daylight hours, but during rain or dew periods, especially at night, it was primarily through surface adsorption.

Godzik *(1968)* observed that the greatest amount of sulfur was absorbed by leaves of a *Betula* species, which is resistant to $SO_2$, and the least by a *Picea* species, which is susceptible to $SO_2$. He concluded that the susceptibility of species is not governed by the amount of pollutant absorbed. Conversely, Materna and Kohout *(1963)* concluded that susceptible species absorbed more pollutants than resistant trees.

Ozone reportedly causes stomatal closure in a number of plant species. Rich and Turner *(1972)* observed this and concluded that closure also depended on plant hydration, atmospheric humidity, and plant species.

Tingey *(1968)* reported that aerial pollutant concentration affected the uptake rate. He found that the initial rate of uptake of $NO_2$ by alfalfa and oats was directly proportional to the concentration of $NO_2$ over the range of 0 to 24 pphm. However, as the length of exposure increased, the rate of uptake remained linear from 0 to 8 pphm but became nonlinear over the range of 8 to 24 pphm. The rate at which the pollutant was metabolized, translocated, or otherwise removed from the absorption site appeared to limit the rate of uptake of the pollutant.

Hill *(1971)* examined the uptake of aerial pollutants by alfalfa and found gaseous uptake in chambers approximated those measured under field conditions. Alfalfa absorbed gaseous pollutants from the atmosphere in the following order: $HF > SO_2 > Cl_2 > NO_2 > O_3 > PAN > NO > CO$. Uptake was influenced by wind velocity, height of canopy, and light intensity.

### Vegetation as Gaseous Sinks

Hill *(1971)* calculated that a square mile of alfalfa could remove $SO_2$ at the rate of $7.25 \times 10^6$ lbs $yr^{-1}$ and $NO_2$ at the rate of $2.04 \times 10^5$ lbs $yr^{-1}$. Based on these figures, he concluded that vegetation could be a significant sink for gaseous emissions in polluted areas. Tingey *(1968)* measured the foliar uptake rate of $NO_2$ by oats and alfalfa. His data indicated plant removal of $NO_2$ could be important in alleviating smog concentrations.

Similar studies have demonstrated that corn seedlings *(Porter and others 1972)* and soybeans *(Hutchinson and others 1972)* are effective sinks for atmospheric ammonia.

Rich and associates *(1970)* measured the rate of uptake of $O_3$ by bean leaves. They found that the conditions favoring transpiration also influenced uptake of $O_3$. Their data suggested that in theory a forest could remove about one-eighth of the $O_3$ content of the atmosphere in 1 hour and could reduce $O_3$ levels from 14 pphm at the top of the canopy to 7 pphm at its base.

Ledbetter and others *(1960)* demonstrated with labeled $F^{19}$ that tomato leaves take up gaseous fluorine from the atmosphere. Similar findings of foliar uptake are reported by Weinstein *(1961)*, Dassler *(1969)*, and Knabe *(1970)*.

Data on the uptake of numerous gases by a standardized plant canopy of alfalfa have been provided by Bennett and Hill *(1973)*.

Thorne and Hanson *(1972)* compared the relative abilities of various plant species to remove ozone from their microenvironment under laboratory conditions. The authors concluded that herbaceous species absorb more ozone than woody species. For example, they demonstrated that *Petunia hybrida* had a velocity of deposition of 13.7 cm $min^{-1}$ while *Quercus engelmanii* had a rate of only 1.5 cm $min^{-1}$. Nevertheless, increasing evidence is being accumulated that woody plants may effectively remove atmospheric trace gases.

Two criteria were recommended by Flemming *(1967)* for curtailing emission levels in forest woodlands. First, the pollution concentration must decrease with elevation. Second, the distance of the forest belt from the pollution source should not be too far. Flemming cited Wentzel's *(1962)* report as an example of a forest belt fulfilling these criteria.

In Western Germany, Bernatzky *(1968)* has investigated the importance of protective plantings against air pollution for 25 years. He believes tree plantings can substantially assist in cleaning up polluted air if (1) tolerant tree species are planted, (2) meteorological and topographical conditions are properly evaluated, and (3) proper planting designs are used. To reduce gases, he stated, dense stands are needed whose areas are at least 5 times the height of the stand at the windward side and 25 times at the leeward side.

Townsend *(1974)* worked on the sorption rates of $O_3$ and $SO_2$ of several seedlings. White oak and white birch removed larger quantities of $O_3$ than red maple and white ash, the least efficient of the nine species investigated. No consistent relationship existed between uptake rate and reported ozone susceptibility.

Roberts *(1974)* concluded that the foliage of certain woody plants (including some commonly planted urban trees) may significantly reduce ambient $SO_2$ levels in the microenvironment immediately surrounding individual leaves.

In opposition to the generally accepted belief that trees can reduce gases, Lampadius *(1963)* concluded that the ad- or absorption of $SO_2$ occurring in the crown levels of trees compared to atmospheric concentrations was negligible. He did suggest that woodlands were most effective as a buffer against injurious climatic elements, which may in turn increase tree susceptibility to $SO_2$ damage. Materna and Kohout *(1963)* compared $SO_2$ emis-

sion levels in coniferous woodlands. Their conclusions coincided with those of Lampadius.

## FATE OF TRANSFERRED POLLUTANTS

A most critical concern in the consideration of trees as pollutant sinks relates to the fate and impact of the contaminant once transferred from the atmosphere of the tree. The impact of transfer is variable and depends on the nature of the pollutant. In exposure to very low levels of reactive materials such as $O_3$ and PAN, the conversion to nontoxic innocuous compounds is probably quite rapid, with no detectable or significant tree perturbation. In the case of $SO_2$, $NO_2$ and $NH_3$, conversion may proceed to compounds useful as nutrient sources. Nitrogen, for example, may be absorbed from the atmosphere and utilized. Porter and associates *(1972)* measured the uptake of $NH_3$ and its metabolism by plants. Approximately 7 to 16 percent was translocated to the plant roots. If absorption is large enough, particularly with regard to nitrogenous gases and the nitrogen budget, the long-term impact on some trees may be stimulatory. Thomas and associates *(1944)* suggested that $SO_2$ is absorbed into the cell in the form of sulphurous acid. This acid is oxidized by some means within the cell and converted to sulfate. In this form it may be translocated and utilized by the plant.

Recent studies with radioactive sulfur have confirmed this conclusion. Fried *(1948)* found that $^{35}SO_2$ was absorbed by vegetation and subsequently translocated to other parts of the plant. He concluded that $SO_2$ from the atmosphere is a source of sulfur nutrition for plants. Similar results were observed by Jensen *(1963)*.

DeCormis and associates *(1969)* measured the uptake of $^{35}SO_2$ in tomato plants. They found radioactive sulfur in both organic and inorganic forms throughout the plant. Materna and fellow workers *(1971)* measured the transfer of sulfur within trees. Movement occurred not only between individual parts of a branch, but also within the whole tree. After the transfer of absorbed pollutants to the roots, some of the pollutants may diffuse into the soil. DeCormis and associates *(1969)* and Fried *(1948)* reported radioactive sulfur in liquid media around the roots of plants exposed to $^{35}SO_2$. Romney *et al. (1969)* reported similar results with fluorine.

With regard to accumulative and recalcitrant materials such as chloride, fluoride, and heavy metals, their fate become particularly critical. Precipitation may act to wash or leach these materials from the plant to contaminate the soil below. In cities with leaf-collection programs, fate of persistent air contaminants (especially heavy metals) must be considered in regard to leaf-disposal methods. If, for example, leaves are burned are, the particulates reintroduced to the atmosphere?; if they are buried at landfill sites, could leaf contaminants pollute the soil or ground water?

## SELECTION AND BREEDING CRITERIA TO MAXIMIZE TREE SINK FUNCTION

If trees are capable of reducing urban air-pollution loads below some meaningful biological or economical threshold, what are some of the selection and breeding criteria appropriately employed in new planting programs?

1. Trees selected or bred to provide this amenity function must be tolerant of the acute adverse influences of air pollution. Clearly, if the tree is severely damaged or killed by one or an interaction of air contaminants, its utility as a sink will be short-lived. In addition to air-pollution tolerance, suitable tree varieties should be capable of withstanding other urban stresses such as poor soil aeration and drought, nutrient deficiencies, and microclimatic extremes. A suitable variety should be

capable of more than mere persistence in the urban environment. It should be able to grow vigorously. Vigorous growth will require maximum stomatal aperture and insure maximum uptake of gaseous pollutants.

2. Coniferous species retaining their foliage year-round may appropriately be favored over decidous species. The atmospheric burden of both particulates and gases is generally higher in winter than in summer for most urban areas. It is important, therefore, to have maximum plant surface available for absorption and adsorption during the winter months. Since evergreen foliage persists longer than deciduous foliage, the opportunity for pollutant removal is correspondingly longer. The morphology of coniferous foliage (for example, pine, spruce, fir) results in a high surface-to-volume ratio, which may be instrumental in more efficient removal rates.
3. Since petioles are especially efficient particle receptors, species with long petioles (for example, ash, aspen, maple) may be favored.
4. Surface hairiness on plant parts (leaves, twigs, petioles, buds) may be especially effective for retention of particles. Those species possessing these hairs (for example, oak, birch, sumac) should be considered.
5. Species with small branches and twigs should be selected or bred over species with large branches or twigs as the former are more efficient particle collectors.
6. Since gases are removed from the atmosphere primarily by the stomates, species should be selected or bred with maximum stomatal capacity for absorption. This ability may be related to absolute stomate number per unit of leaf surface, size of stomatal aperature, and length of time the stomates are open.
7. Species should be selected or bred that have maximum resistance to stomatal closure occasioned by environmental variables such as moisture availability, temperature, wind, light intensity, and air pollution.
8. In selection and breeding, one should consider the relative ability of tree species to utilize pollutant gases as partial sources for required nutrients.

## SUMMARY

We have considerable evidence indicating that trees in urban environments have considerable potential to remove both particulate and gaseous pollutants from the atmosphere. In the case of particulates, much of this evidence comes from experiments employing particles larger than most that are present in urban atmospheres. Further, much of this evidence was accumulated in nonurban environments with objectives unrelated to air pollution. In the case of gaseous pollutants, much of the evidence comes from controlled environmental studies with nonwoody species. We do not have adequate information to document the ability of trees to remove meaningful quantities of pollutants from actual urban atmospheres. Trees have yet to be shown capable of reducing a particular air contaminant below a significant threshold of effect for any urban area. Models must be developed so that the ability of specific plantings to remove contaminants can be estimated for specific urban environments.

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# SELECTION OF TREES FOR TOLERANCE OF AIR POLLUTANTS

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*ABSTRACT.* Sources of pollutants and pollutant injuries to plants are briefly described. The basis for ranking tree species in susceptible, intermediately susceptible, and tolerant to sulfur dioxide and to ozone are given. While these lists must be used with caution, they do indicate appreciable differences among woody plants in susceptibility. Nurserymen and arborists can use such lists in producing and selecting trees for specific environments. Plant breeders should capitalize on the differences in susceptibility in creating or selecting hybrids and cultivars that are sufficiently tolerant to different sets of environments.

SOURCES OF AIR POLLUTION can be classified into five major categories (table 1). The pollutants arising from these sources may be categorized arbitrarily as general (all air pollutants) and those that injure plants (phytotoxic pollutants). Transportation is a significant source for both categories. It, industry, and the generation of electricity represent the major sources of phytotoxic air pollutants.

Sulfur dioxide and ozone are probably responsible for more air-pollution injury to woody plants than all other air pollutants combined. Fluorides may cause extensive tree damage around large point sources such as smelters or fertilizer plants, but are probably not as significant as sulfur dioxide and ozone. Ethylene, ammonia, chlorine, hydrogen chloride, dusts, and heavy metals are also capable of injuring woody plants to some extent.

However, the influence of these minor pollutants is often limited to a localized

Table 1. Sources of general air pollutants and phytotoxic air pollutants

| Source | All major pollutants | Phytotoxic pollutants |
|---|---|---|
| | *Percent* | *Percent* |
| Transportation | 60 | 28 |
| Industry | 18 | 30 |
| Generation of electricity | 14 | 26 |
| Space heating | 5 | 9 |
| Refuse disposal | 3 | 7 |

area surrounding a spill, leak, or industry. In contrast, tree damage from sulfur dioxide or ozone can be much more extensive. Since these two pollutants are generally recognized as the most important gaseous air pollutants in the United States, this report will deal primarily with selecting trees resistant to sulfur dioxide and ozone.

## SOURCES OF SULFUR DIOXIDE AND OZONE

The burning of coal accounts for nearly 60 percent of the sulfur dioxide released annually in the United States. Upon burning, the sulfur in the coal is converted to sulfur dioxide; thus, the higher the sulfur content of the coal, the more sulfur dioxide released. The production, refining, and utilization of petroleum and natural gas adds another 20 percent to the sulfur dioxide emission. Ore smelting and refining (principally iron, lead, zinc, copper, and nickel) produce 7 percent of the sulfur dioxide emissions. The remaining sulfur dioxide in the atmosphere originates mainly from industries that manufacture or use sulfuric acid and sulfur. Natural sulfur dioxide arises from various sources, including volcanoes.

Ozone is a natural component of our air, existing in the upper atmosphere, where it filters out dangerous ultraviolet radiation. Turbulence and vertical downdrafts may occasionally bring down small quantities of ozone to ground level. Small amounts of ozone are also formed by electrical discharges such as lightning. These sources are of minor importance, however, when compared to the amounts of ozone formed in our urban environments. Hydrocarbons and oxides of nitrogen are emitted into the atmosphere from automotive exhaust. Once in the atmosphere, these compounds undergo photochemical reactions in the presence of sunlight, producing ozone along with a variety of other compounds. Ozone formed in this manner may travel long distances and cause plant injury.

## INJURY TO PLANTS

Air-pollution injury to plants is often classified as chronic or acute. Chronic symptoms usually imply tissue injury but not death, while acute injury signifies tissue death. Chronic symptoms often result from exposure of a plant to low levels of pollution for a long time, or occur when a plant is fairly resistant to a pollutant. Acute injury occurs after a short-term high level of pollution, or to very sensitive plants.

Typical sulfur dioxide injury on broadleaved trees appears as areas of injured tissue between the veins. The interveinal injured tissue appears yellow in chronic cases, or ivory to tan in acute cases as the tissues die. The cells and tissues adjacent to the veins usually remain green, resulting in the characteristic pattern.

Acute sulfur dioxide injury on conifers usually appears as a reddish-brown discoloration of the needle tip. The discoloration may progress towards the needle base in severe cases. Chronic injury may also involve some tipburn, but mainly is observed as a general yellowing of needles followed by premature defoliation of older needles. The defoliation may give the crown a sparse, tufted appearance. A young seedling may become severely dwarfed by repeated assaults over a period of time.

Ozone symptoms on broadleaved trees appear as small flecks or stipples of light colored or reddish-purple tissue on the *upper* leaf surface. Individual spots of this type are usually less than ⅛ inch in diameter. Injury is not produced on the lower leaf surface.

Acute ozone injury to conifers often results in death of the needle tip, or in severe cases, death of the entire needle. In less severe cases, chlorotic mottling is observed when small patches of yellow or brown injured tissue alternate with green healthy patches of tissue. As with most pollutants, ozone may induce premature defoliation of older needles, giving the tree a tufted appearance.

## SUSCEPTIBILITY TABLES

If an arborist wishes to plant trees that are resistant to the common air pollutants, he usually seeks listings of the susceptibility of various species to different air pollutants. Although such lists are useful to a degree, they also possess inherent limitations, which must be understood. Some of the limitations and problems with such lists follow.

### Criteria for Ranking Species

The relative rank of a plant species or variety in its susceptibility or tolerance to a given air pollutant is often influenced by the criterion used for ranking. Criteria range from cellular or physiological effects to changes in species composition or succession in a plant community. The same species may be ranked quite differently depending upon the criterion utilized.

Criteria used to assess susceptibility are sometimes based upon the ultimate use of the plants. Timber species or fruit trees may be rated by direct loss of yield; ornamentals or Christmas trees by foliar discoloration. Trees used for wildlife management, recreation, or watershed stabilization may require more complex rating schemes, because they can tolerate different amounts of injury and still fulfill their primary functions. Regenerative capacity, regardless of degree of foliar injury, is very important and must also be considered.

Foliar injury is often one of the early manifestations that leads to the other effects. It is an obvious symptom, fairly easy to estimate or measure. Thus the majority of the species contained in such lists are ranked by percentage of foliar injury induced by a given air pollutant. However, when several small lists of susceptibilities are combined into a large table, the species within the table will be ranked according to different criteria; and some comparisons within the table may not be valid.

### Basis of Original Data

Another aspect that must be considered when using susceptibility tables is the manner in which the original data were collected. Data may have originated from: field observations of injury on native vegetation; symptoms on vegetation purposely transplanted into an area suffering from air pollution; artificial exposure of various species in chambers in the laboratory or in the field; and artificial exposure of plants in the field without the use of chambers.

Each method has its advantages and limitations. Field observations and rankings may be complicated by the presence of other air pollutants, especially in industrial regions. Symptom intensity may vary with genotype and locality. In addition, field observations near a long-established source of air pollution may reflect only the relative susceptibility of a residual tolerant plant population, since highly susceptible individuals or species would have died long ago. It is also sometimes useful to know the highly susceptible species. Transplanting species into an area overcome this latter problem, but results are still influenced by local factors.

Artificial exposure of trees in chambers is usually restricted to studying the influence of single pollutants on small seedlings. Results from such studies do not necessarily correlate with field observations of mature stands exposed to the multiple pollutants present in many areas. Environmental conditions within the exposure chamber may also bias the results, since it is difficult to duplicate ordinary field conditions. Fumigation techniques may vary among researchers, further complicating the resulting susceptibility ratings. Also, it is imperative that each plant species or variety be identified as clearly as possible, because definite interspecific as well as intraspecific differences in susceptibility may occur within the same genus.

### Geographic Location

Many susceptibility lists are derived from plants growing in various countries of the world. This is an important consideration, when using susceptibility tables, because pollutant regimes, plant genotypic and phenotypic characteristics, seed source, environmental parameters, etc. differ radically from country to country. These differences may in turn drastically affect relative susceptibility. Plants listed as resistant to city air pollution in industrialized cities of Europe may be subjected to entirely different pollutants than those in Washington, D.C. In the former case, trees might be subjected simultaneously to sulfur dioxide, chlorides, fluorides, heavy metals, etc. In Washington, Los Angeles, or Philadelphia, resistance to ozone may be the primary prerequisite for a tree to tolerate air pollution. An arborist seeking pollution-resistant trees must first acquire a listing of the phytotoxic air pollutants prevalent in his area.

## VALUE TO ARBORISTS

In spite of the above considerations, a listing of the relative susceptibility of various plant species to specific air pollutants can be useful to arborists. Field observations have supported results obtained from artificial fumigations, and vice versa, especially at the extremes of susceptibility or tolerance. Species found to be extremely tolerant in artificial exposures seldom develop injury from that specific air pollutant under ambient conditions. Likewise, artificial exposures usually produce injury on species known to be very susceptible to ambient levels of a specific air pollutant. However, the broad category of intermediate susceptibility is of less value, since sensitivity of these species to a given pollutant may vary with genotype or different environmental conditions.

In summary, compilations or lists of relative susceptibility of plant species to air pollution must be used with caution and understanding. Rankings at the extremes of susceptibility or tolerance are most useful, while those in an intermediate category are less useful. Also, these lists cannot begin to estimate the tolerance of a species to the multitude of other stresses to which it may be subjected. This is best done by planting and observation.

Tables 2 and 3 of this report were based on a thorough literature review. Original references were searched for susceptibility lists and tables. The senior author's personal comments and observations were also used to categorize species. A list of the references that were searched may be obtained from EPA, Corvallis, Oregon.

## OPPORTUNITIES IN TREE BREEDING

Large genetic differences in resistance to air pollutants have been found among species, races within species, and individuals within populations. Therefore, it is possible for plant breeders to select and breed cultivars that will have greater resistance to phytotoxic gases. Just how much effort should go into such breeding work is not at all clear at this time, however.

Control of emissions may reduce or stabilize the levels of certain air pollutants in the most severely affected areas, but in the foreseeable future we will continue to have an appreciable spread in the amount of pollution. Air quality standards are being set at levels that safeguard the health of humans, but not always the most sensitive plants. Resistant cultivars would be especially useful in species that are frequently injured, or in which there are detrimental effects on growth or general health.

Evidence of variation in resistance has been found in at least 15 tree species through controlled experiments in fumigation chambers and also through comparisons in nature after pollution episodes. The latter are more useful for purposes of selection, as the actual con-

## Table 2.—The relative susceptibility of trees to sulfur dioxide

| Sensitive | Intermediate | Tolerant |
|---|---|---|
| *Acer negundo* var. *interius* | *Abies balsamea* | *Abies amabilis* |
| *Amelanchier alnifolia* | *Abies grandis* | *Abies concolor* |
| *Betula alleghaniensis* | *Acer glabrum* | *Acer platanoides* |
| *Betula papyrifera* | *Acer negundo* | *Acer saccharinum* |
| *Betula pendula* | *Acer rubrum* | *Acer saccharum* |
| *Betula populifolia* | *Alnus tenuifolia* | |
| | | *Crataegus douglasii* |
| *Fraxinus pennsylvanica* | *Betula occidentalis* | *Ginkgo biloba* |
| *Larix occidentalis* | *Picea engelmannii* | *Juniperus occidentalis* |
| *Pinus banksiana* | *Picea glauca* | *Juniperus osteosperma* |
| *Pinus resinosa* | *Pinus contorta* | *Juniperus scopulorum* |
| *Pinus strobus* | *Pinus monticola* | |
| *Populus grandidentata* | *Pinus nigra* | *Picea pungens* |
| | *Pinus ponderosa* | *Pinus edulis* |
| *Populus nigra* 'Italica' | | *Pinus flexilis* |
| *Populus tremuloides* | *Populus angustifolia* | *Platanus* X *acerifolia* |
| *Rhus typhina* | *Populus balsamifera* | *Populus* X *canadensis* |
| *Salix nigra* | *Populus deltoides* | |
| *Sorbus sitchensis* | *Populus trichocarpa* | *Quercus gambelii* |
| *Ulmus parvifolia* | *Prunus armeniaca* | *Quercus palustris* |
| | *Prunus virginiana* | *Quercus rubra* |
| | *Pseudotsuga menziesii* | *Rhus glabra* |
| | | *Thuja occidentalis* |
| | *Quercus alba* | *Thuja plicata* |
| | *Sorbus aucuparia* | *Tilia cordata* |
| | *Syringa vulgaris* | |
| | *Tilia americana* | |
| | *Tsuga heterophylla* | |
| | *Ulmus americana* | |

## Table 3.—Relative susceptibility of trees to ozone

| Sensitive | Intermediate | Resistant |
|---|---|---|
| *Ailanthus altissima* | *Acer negundo* | *Abies balsamea* |
| *Amelanchier alnifolia* | *Cercis canadensis* | *Abies concolor* |
| | | *Acer grandidentatun* |
| *Fraxinus americana* | *Larix leptolepis* | *Acer platanoides* |
| *Fraxinus pennsylvanica* | *Libocedrus decurrens* | *Acer rubrum* |
| | | *Acer saccharum* |
| *Gleditsia triacanthos* | *Liquidambar styraciflua* | |
| *Juglans regia* | *Pinus attenuata* | *Betula pendula* |
| | | *Cornus florida* |
| *Larix decidua* | *Pinus contorta* | *Fagus sylvatica* |
| *Liriodendron tulipifera* | *Pinus echinata* | *Ilex opaca* |
| | | *Juglans nigra* |
| *Pinus banksiana* | *Pinus elliottii* | *Juniperus occidentalis* |
| *Pinus coulteri* | *Pinus lambertiana* | |
| *Pinus jeffreyi* | *Pinus rigida* | *Nyssa sylvatica* |
| *Pinus nigra* | *Pinus strobus* | *Persea americana* |
| *Pinus ponderosa* | *Pinus sylvestris* | *Picea abies* |
| *Pinus radiata* | *Pinus torreyana* | *Picea glauca* |
| *Pinus taeda* | | *Picea pungens* |
| *Pinus virginiana* | *Quercus coccinea* | |
| | *Quercus palustris* | *Pinus resinosa* |
| *Platanus occidentalis* | *Quercus velutina* | *Pinus sabiniana* |
| *Populus maximowiczii* X | | *Pseudotsuga menziesii* |
| *trichocarpa* | *Syringa vulgaris* | *Pyrus communis* |
| *Populus tremuloides* | | *Quercus imbricaria* |
| | *Ulmus parvifolia* | *Quercus macrocarpa* |
| *Quercus alba* | | *Quercus robur* |
| *Quercus gambelii* | | *Quercus rubra* |
| | | |
| *Sorbus aucuparia* | | *Robinia pseudoacacia* |
| *Syringa* X *chinensis* | | *Sequoia sempervirens* |
| | | *Sequoiadendron giganteum* |
| | | *Thuja occidentalis* |
| | | *Tilia americana* |
| | | *Tilia cordata* |
| | | *Tsuga canadensis* |

ditions that plants encounter are represented. These include mixtures of pollutants, stresses caused by other disease incitants, and other variables that may not be tested adequately in fumigation chambers. The relative susceptibilities of trees to polluted air of cities and industrial regions have been studied extensively in Germany, but only fragmentary information is available for North America.

Most research aimed at developing resistant cultivars has been concerned with selection methodology. Several ways of testing resistance have been used successfully, and in a few cases the results of rapid tests have been verified through subsequent pollution exposures under field conditions. The most reliable way of utilizing resistant plants is to propagate them vegetatively. Clonal materials are propagated extensively in landscape-tree nurseries, so it should be relatively simple to exploit resistant individuals once they have been identified.

Two kinds of research on air-pollution resistance seem to be justifiable in view of our present state of knowledge. (1) The relative resistance of cultivars that are in use now should be determined, so that better planting recommendations can be formulated for severely polluted localities. (2) In the more sensitive species, genetic studies of pollution resistance should be started or extended, so that resistant cultivars can be developed through selection and breeding.

In the meantime, arborists can interpret tabulated information in this report and others in the light of their own observations. The most severe kinds of damage can be avoided in this way, but many frustrations may be encountered until more precise information and more resistant cultivars become available.

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# SELECTION OF TREES FOR ENDURANCE OF HIGH TEMPERATURES AND ARTIFICIAL LIGHTS IN URBAN AREAS

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*ABSTRACT.* In urban areas, high temperatures and artificial lights may adversely affect the growth and survival of trees already under various forms of stress. Trees close to radiative surfaces such as pavements, walls and heat vents are especially susceptible to heat damage. However, harmful effects, if any, by prolonged illumination upon urban-grown trees are yet to be experimentally determined. Specific selection or breeding programs to identify species or cultivars with resistance to thermal and light pollution are not economically warranted. However, some research on heat resistance could be combined with drought studies, and light influences could be included in studies of low-temperature effects on trees.

## URBAN CHALLENGES

LONG RANGE PLANNING and programming to provide hardy, attractive trees for urbanized ecosystems are speculative at best. But current studies offer mechanisms to better comprehend the complexities of planning that link the social, physical, and biological systems within cities *(Powell 1972)*.

Urban foresters and tree breeders are plagued by the same dilemma that torments any forecaster: namely, how does one predict future events? Forecasters often rely upon previous events to assess a predictable future *(Kahn and Bruce-Biggs 1972)*. Managers and researchers concerned with the culture of urban vegetation also aspire to the role of optimistic visionaries, but are faced with the responsibility of producing and maintaining publicly acceptable trees and shrubs for an unpredictable future.

In addition to foreseeing the cultural vagaries and social imponderables of the immediate future, the tree breeder faces a challenge foreign to his training. His ancillary task is to judge what form the political, economic, and ecological environments will have when his selected species and cultivars develop to maturity along the streets and in the open spaces of an ever-urbanizing globe. *Wunderbäume* that incorporate traits assuring survival and growth in a hostile metropolitan environment are the breeder's goals in selection, breeding, development, testing, production, distribution and hoped-

for public acceptance. But he may fall victim (as he has done in the past) to political or economic changes by the time his prize tree is ready for large-scale distribution. Let's hope he will estimate correctly!

In contributing to the welfare of urban people, arborists and tree breeders have a special obligation to provide durable metropolitan trees. However, within the urban environment, excessive heat and prolonged periods of outdoor artificial light might play a capricious role in the growth and survival of trees recommended by the breeder.

These two urban climatic phenomena are of special current significance, because there has been a gradual and continuing increase in external tree temperatures both above and below soil or pavement level, and a steady increment of street lighting in urbanized areas as compared to rural counterparts. But, paradoxically, we may face the possibility of a reversal of the foregoing trends if, in the immediate future, a limit is placed on urban consumption of energy. Thermal and light pollution could be dramatically reduced through use restrictions or rationing. Thus the illuminated heat domes that now cover our major and minor cities may dim and cool.

To anticipate the effects of heat and light that may possibly confound the breeder's and arborist's endeavours, I shall examine in this paper pertinent cultural and climatic components of the urban ecosystem that may influence tree introduction, describe how trees react to high temperatures and artificial light, and suggest a strategy to incorporate stress-resistance characteristics in a tree-improvement program.

## EXCESSIVE HEAT

In literature describing the heat-light islands that surround major metropolitan centres of the world, there is an abundance of material on temperature differences between urban and rural areas, but little information on changes due to outdoor artificial lights. In his review of literature describing the climates of cities, Peterson *(1969)* also noted that temperature is the best documented component of meteorological differences between urban and rural areas.

There are currently two major sources of increased temperatures affecting tree growth in cities. Urban conditions of mid and high latitudes produce a consistently higher temperature by 2 to 5°C than that of rural areas. However, radiation and fluctuation of ultrahigh temperatures in areas adjacent to the foliage and bark of city trees are important as a microclimatic stress than the background increase in temperature. A third and future source is cosmopolitan thermal-power outputs. This source of heating the city environment may increase by five times the present level by the year 2,000, but is not predicted to influence global climate *(Wilson et al. 1970)*. However, as suggested by the participants of the Study of Critical Environmental Problems *(SCEP)*, heat domes or islands may generate regional climatic effects as they enlarge.

### General Temperature Changes

Temperature data showing the general effects of cities are abundant *(Sekiguti 1970)* and have been reviewed by Bach *(1972)*, Bryson and Ross *(1972)*, Peterson *(1969)*, and Terjung *(1974)*.

Cityscapes contribute to thermal accretion in several ways *(Lowry 1967)*: (1) additive surface area of buildings with large horizontal and vertical faces provides suitable conditions for substantial exchanges of energy; (2) facing materials are rocklike, with high conductivities, heat capacities, and albedos; (3) cities generate supplemental heat because of human metabolism, traffic, industrial activities, domestic heating, and air-conditioning condensers; and (4) impervious surfaces of the city structure lead to a rapid drain of rain and snow, fundamentally altering moisture and heat budgets.

### Neighborhood Effects on Temperatures

Ludwig *(1970)* found that, in the center of large cities where buildings are dense and tall, local outdoor summer climates were several degrees cooler near ground level than in surrounding neighborhoods of dense but low-storied (1- to 5-floor) structures. As Ludwig suggested, that difference is due at least in part to the black flat-topped roofs that predominate in row-house areas and produce high absorption of radiation during hot summer days. Suburban fringes that included dispersed green space were several degrees cooler than the city center.

His observations are important in our consideration of heat stress on trees. We can expect that greater temperature stress will occur along city streets in areas of row houses and small shops than in the central core of tall buildings. However, the former areas constitute about 80 percent of the urban space in many cities.

Differences between neighborhoods and within neighborhood vary with the general weather conditions. As Oke and Hannel *(1970)* wrote of their study of Hamilton, Ontario, differences at street side are especially pronounced under clear, calm conditions. Various surfaces can then exert their effect on microclimate, and not have it modified by advection.

In his analysis of the thermal microclimate contiguous to a five-story urban brick building, Landsberg *(1970)* measured, with an infrared thermometer, the temperature of several surfaces that would be close enough to urban trees to influence their metabolism. On a bright, summer day at 4:00 p.m. he found the temperatures of a west-exposed wall and a parking-lot pavement to be over 45°C, the surface of a grass lawn to be 33°C, and the air over the grass and an enclosed paved courtyard to be 31°C. Repeated observations and further data from Columbia, Maryland, were similar. Infrared radiation reaching trees from adjacent emitters might heat the surfaces, especially of bark, to temperatures similar to the source. If tree tissues are already under moisture strees, such temperatures might have damaging, possibly sometimes lethal, effects.

## ARTIFICIAL LIGHT

Within a large metropolitan center, artificial light is emitted from a variety of sources. Though background thermal escalation is invisible to the eye, the loom of light that marks the location of an urban complex is readily visible from afar in the countryside. Street lamps, commercial advertising displays, and flood-lit shopping centers contribute to the nocturnal urban glow. To these we can add light from office buildings, car and other vehicular headlights, light filtering through house windows, decorative residential and landscape lighting, security lamps, and 24-hour flood-lit recreation facilities that are increasing at a phenomenal rate.

At present there are some 12.5 million street and highway lights in service in the contiguous United States of America. Mercury vapour lamps dominate the total with 75 percent, followed by incandescent lamps at 20 percent; and high-pressure sodium vapour, metal halide, fluorescent, and miscellaneous lights make up the other 5 percent. During the past 10 years there has been a marked decline in incandescent lamps, which have been replaced mainly by mercury vapor. A trend toward high-pressure sodium vapor (HPS) began with the invention of Lucalox in 1966. A number of major cities in the United States began installing large numbers of HPS about 5 years ago. Today about 3 percent of our large city street lights are HPS *(Buck 1975)*. Recently the Chicago Department of Streets and Sanitation installed some 40,000 HPS lamps.

Collectively and individually, various city lights may strike trees and shrubs with intensities of from a fraction to 20 or 30 footcandles (1 fc=10.8 lux, m-c), the average being 1 to 3 footcandles *(Andresen 1974)*. In addition to quantity,

the quality of radiant energy (wavelength) also varies by source of filament or ionized gas.

During normal periods of daylight, urban trees are exposed to direct and reflected radiant energy including wavelengths between 380 and 760 nanometers (nm)=millimicrons—the visible spectrum. Electrically actuated lamps also incorporate wavelengths between 380 and 760 nm, but emit different relative energy per lumen of output at specific wavelengths. For example, noontime natural sunlight emits rather uniform relative energy of 55 percent between 470 and 680 nm, but 500-watt incandescent lamps emit light that has little relative energy in the deep blue range (400 nm) and gradually builds to the peak of a smooth curve in the near infrared (770 nm) at about one-half the energy value of sunlight.

In clear mercury lamps, major resonance radiation occurs at 405, 436, 546, and 578 nm, giving the radiation a bluish-white color. HPS lamps resonate primarily at 589 nm, which provides yellowish-orange coloration. These various concentrations of emissions produce differing plant responses or photoperiodic reactions.

Before discussing the physiological effects of urban heat and artificial light on trees and shrubs, I should emphasize that these two factors of the urban climate are not independent of one another nor of other components. Complex interactions of these and other factors make difficult an assessment of the roles of increased heat and light on tree growth and survival in urban areas.

## PHYTORESPONSE

For our discussion of the capacity of trees and shrubs to resist detrimental effects from heat and light of metropolitan centers, the terms thermotolerance and thermoavoidance, as explained by Levitt *(1972)*, are helpful. Thermotolerance, a synonym for heat resistance or thermoresistance, is the ability of trees, shrubs, and other woody plants to survive heat stress on internal tissues. Thermoavoidance or heat avoidance, on the other hand, suggests the ability to adjust to or resist lethal or injurious external infrared radiation.

### Thermotolerance

Tolerance to heat by woody plants has been reported by Lange *(1965, 1967)*, but most of these and his earlier studies dealt with the killing of leafy twigs or small woody plants by heat. Lorenz *(1939)* immersed five species of forest trees in hot-water baths to determine the heat of protein coagulation of cortical tissues. Transplants (2-1) of *Pinus strobus*, *P. resinosa*, *Picea glauca*, *Catalpa speciosa*, and *Ulmus americana* were treated.

Based on a number of studies (including Lorenz') reviewed by Levitt *(1972)*, the conclusion is that protoplasmic disturbance becomes irreversible between 49 and 51°C in most woody plants. However, cellular death varies with duration of exposure to high temperatures and with the degree of maturity of the subjected tissues. Little if any work has been done on entire mature trees or their component leaf, bark, or root systems. Hence, thermotolerances of urban planted trees of various size classes are yet to be determined.

### Thermoavoidance

Heat avoidance can occur through: (1) insulation, (2) respiration, (3) absorption of radiant energy, and (4) transpiration cooling. The last two have the most importance *(Levitt 1972)*.

Thick and highly corky bark of tree stems and trunks normally serves as insulation under frigid conditions, but may actually deter conductive heat transfer from or into internal tissues. However, through translocation streaming, high internal temperatures can be dissipated upward and outward by transfer to cortical and parenchymous cells of thin bark shaded by the canopy.

The role of respiration is still theoreti-

cal, but a lowered respiration rate might conceivably induce avoidance.

Decreased absorption of radiant energy results in part from certain reflective characteristics of leaf and bark surface. Glabrous leaves and white-colored bark seem most effective in reflecting radiation of 775 to 1100 nm. Transmissibility also plays a role in decreased absorption: that is, thin, pale-green leaves transmit more radiant energy than thick, dark-green leaves. And absorption of infrared radiation by epidermal leaf cells high in water content could protect the protoplasmic mesophyll.

Transpirational cooling, although formerly exaggerated, can lower internal leaf temperatures 2 to 5°C, or perhaps more, below surface conditions. This decrease may be just enough to reduce tissue temperatures below the lethal range.

### Photoperiodism

Photoperiodic responses of plants have long been a favorite laboratory demonstration and subject of studies, and have been economically vital to commercial floriculture and horticulture; but the responses of woody plants are yet to be fully explored. This is especially true of mature trees growing under total urban stress, including artificial light.

In his comprehensive review of photoperiodism in woody plants, Wareing *(1956)* surveyed the earlier literature. During the 20 intervening years since then, about 15 papers and further reviews have been published on this subject *(Andresen 1974; Cathey and Campbell 1973, 1975; Downs 1958; Downs and Borthwick 1956; Nitsch 1957)*. However, no controlled or replicated tests have been conducted with large trees growing in an outdoor urban environment subject to various sources and intensities of artificial illumination.

Wareing *(1956)* also tabulated some 60 species of 31 woody genera that were photoperiodically sensitive in producing extended growth. But most of his plants were juvenile forms tested under growth-conducive greenhouse or nursery conditions with a broad variety of lighting regimes. Manipulation of photoperiod and favorable temperatures can produce continuous seedling growth in such species as *Liriodendron tulipifera* and *Robinia pseudoacacia;* but *Pinus sylvestris, Acer pseudoplatanus,* and *Phellodendron amurense* assume varying froms of winter dormancy *(Wareing 1956)*.

Downs *(1958)*, working with fluorescent and incandescent sources of light, found that 30 fc of 8 additional hours of incandescent light significantly increased stem elongation of *Catalpa bignonioides, Hibiscus syriacus,* and *Pinus taeda* over that produced under 8-hour days or supplemental fluorescent illumination. He surmised that increased amounts of far-red wave lengths from incandescent lamps produced the pronounced elongation effects. Downs also reasoned that—in general—short photoperiods induce dormancy, long days (natural or artificial) prolong periods of vegetative growth, and long days can break the dormancy induced by short photoperiods. Nevertheless, as Wareing *(1956)* and many others have reported, responses to extended photoperiods vary not only within genera but also by ecotype within species.

Wareing summarized his survey of studies on photoperiodic growth and dormacy of juvenile woody plants with the statement: "Thus, conclusions regarding mature trees cannot be arrived at by extrapolation from the photoperiodic behaviour of the seedlings".

For large trees grown in open but non-urban conditions, Wareing suggested that species within the genera *Larix, Populus, Salix,* and *Betula* terminate their annual growth in primary response to onset of short days that are coupled with cooling temperatures, but these species would be responsive to extended illumination until tissues are chilled to dormancy. Other species such as *Alnus glutinosa, Acer pseudoplatanus,* and *Platanus orientalis* (grown at high latitudes) cease growth in June or July and do not respond to

subsequent extension of photoperiods. He also noted that in many woody species the seasonal period of height growth is much shorter in mature trees than in the seedling stage.

Of special interest to the tree breeder is the phenomenon of ecotypic variation of trees in response to photoperiodic regimes. Particular attention should be given to species that possess extensive latitudinal range, such as the North American *Acer saccharum, A. rubrum, Carpinus caroliniana, Ostrya virginiana, Betula nigra,* and *Fagus grandifolia.* Of these, *A. rubrum* appears to be especially responsive to photoperiods *(Cathey et al. 1975).* Wareing *(1956)* reported that when European ecotypes of *Salix, Betula, Populus, Ribes,* and *Vaccinium* were introduced from southern latitudes to regions of high latitude, they suffered from autumn frosts because of extended growth under laboratory conditions.

In summarizing photoperiodic responses, I reiterate Wareing's conclusion that observations of seedling response cannot be projected to large trees. Bickford and Dunn *(1972)* stated that much is yet to be learned about the effects of photoperiod, wavelength, and level of supplemental light on the responses of woody plants. In response to a question about the effect of street lamps on plant growth, Vince *(1970)* observed that, in woody plants, autumnal low temperatures usually override the effect of extended-day length. However, Cathey and Campbell *(1975)* advise detailed studies in the urban environment to determine species and cultivar responses to artificial illumination.

Before I discuss selection and breeding needs in response to heat and light changes, six summary statements are in order.

1. Virtually all experimental and observational studies of woody-plant responses to heat increases and photoperiod extensions (artificial light) have been with seedlings or young transplants grown under greenhouse, nursery, or phytotron conditions.
2. Conclusions about effects on large trees were derived from observations on small segments of tissue without consideration of interactions with other factors.
3. In general and under urban conditions there probably is a strong linkage in trees between: (a) drought resistance and heat resistance, and (b) resistance to post-dormancy response to artificial light and low-temperature hardiness.
4. No large-scale studies have been performed in situ or in simulation of a downtown commercial or residential environment.
5. Applied physiological-genetic tests conducted within the urbanized matrix may be needed now to provide the tree breeder with a "heat-light" selection rationale—*if,* indeed, one is needed.
6. A re-examination of extended photoperiods may show that exposure to various forms of artificial light benefits urban trees.

## SELECTION NEEDS

### The Urban Tree

In his paper on the application of ecological genetics principles to forest tree breeding, Tigerstedt *(1974)* remarked that in the modern context of provenance research "Yield maximization has fallen to second place, ecological stability has taken over". A similar observation could be made here, because in contrast to earlier horticultural selection for beauty, form, and habit, trees are beginning to be selected for survival in urban environments.

Pauley *(1958)* recognized that photoperiodic responses exhibited by trees are under genetic control and thus subject to natural or artificial selection. However, his primary concern was with increasing the net yields of wood or fiber (Tigerstedt's subordinated objective). Tigerstedt also observed that forest geneticists and tree breeders must adopt a com-

pletely new vocabulary that incorporates ecosystem considerations.

As the forest tree breeder moves into the urban arena and attempts to select and breed trees to resist individual or collective stresses, he has the obligation to assure and maintain optimum genetic resilience within his selection or hybrid. This is especially true because agricultural and urbanization practices of both industrialized and developing nations are methodically reducing the gene pools of broadleaved trees. Current clonal-monocultural practices still evident in the arboriculture of most North American cities portend disasters similar to that due to the Dutch elm disease. Future problems resulting from overly uniform planting materials are predictable from observing the contemporary decline of large, widespread urban populations of even-aged and overmature exotic trees such as *Acer platanoides, Aesculus hippocastanum,* and *Platanus acerifolia.*

Santamour *(1969, 1971, 1973)* has established a number of sound selection and breeding criteria for metropolitan environments. Santamour *(1972)* summarized his thoughts in an article in the *1972 Yearbook of Agriculture* as he discussed the development of shade trees for urban areas. His major proposition was that the best trees for any urban area are those, either native or exotic, that have proved capabilities to prosper under prevailing hostile ecosystems. He also warned that municipal foresters and other vegetation managers prefer physical uniformity of trees to facilitate planting and maintenance. This selection practice would, as mentioned, have long-range detrimental effects.

Here then is an educational challenge to convince urban foresters that, even though clonal uniformity may have maintenance advantages, it might result in inordinate costs as diseases or insects strike or when large blocks of trees approach physiological maturity. Planting a variety of species in numerous responsive ecotypes, and spread through a sequence of age classes, holds the answer to low maintenance expenditures. Tigerstedt *(1974)* advocates the breeding of heterotic, multiclonal varieties to guard against uniclonal impotence. He writes that advantages of this concept include less average phenotypic variation than single-clone cultivations; greater ecological adaptability especially regarding host-parasite systems; and if combined optimally, a performance superior to that of pure cultures.

Results of the above suggestions should be judged by Pauley's *(1958)* rule that "Final decisions on adaptability of the proposed introduction to the new habitat must be based on the observed interaction that results between the introduced genotype and all the factors of its new environment".

### Selection Strategy

Is selection specifically for resistance or endurance to high temperatures and artificial lights in urban areas worth the effort? Considering more pressing problems in urban-tree improvement to meet air and soil pollution, soil compaction, related soil alteration, and insect and disease afflictions, I think selection for resistance to high temperature and artificial light has low priority. This conclusion appears reasonable in spite of the current controversy over the effects of HPS on city trees.

I submit the foregoing because we can stretch our resources by combining drought and heat studies, including moisture stress, in one package. Because detrimental effects of artificial light on large, urban-grown trees are yet to be physiologically demonstrated, and because there is an apparent relationship between frost damage and photoperiodic response, low-temperature and light studies should be combined. Further, the minimum cost of conducting a 5-year test of 3 light sources and 10 cultivars replicated 10 times on 3 similar urban sites, would be over $100,000, and the test would require 100 acres of land. In addition, long-range, land-

consuming biological studies in cities face towering difficulties.

In essence, we are searching for trees resistant or tolerant to all the hazards and stresses of urbanized ecosystems—trees that also possess genetic resilience and social acceptability. We must also be prepared to develop specific selections tailored to meet singular requirements. For example, the city forester sets a high priority on minimum-maintenance and pest-free trees, while the home owner might not mind the maintenance but would be interested in a tree of multi-seasonal attraction. Selections desirable within cities should also vary to provide trees adapted to local sites and microclimates.

In conclusion there are several common traits that should be incorporated in all urban trees: resistance to low and high temperatures, drought, pollution, and biologic pests. In addition to these survival traits, we will have to provide varying esthetic and amenity values. Thus our selection challenge not only includes the development of trees for growth and survival in a hostile urban environment, but in addition an assignment to produce trees that satisfy the highly variable needs of our urban residents.

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# DROUGHT AND TRANSPLANTABILITY OF TREES

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*ABSTRACT.* Studies on development of water deficits in trees and their effects on stomatal closure, wilting, photosynthesis, shoot growth, cambial growth, reproductive growth, and injury are reviewed. Drought resistance is discussed in terms of drought-avoiding adaptations (stomatal characteristics, production of leaf waxes, root growth characteristics, and leaf shedding), and desiccation tolerance. Attention is given to important cultural practices controlling water balance of transplants (including time of transplanting, pruning of shoots, site preparation, handling of planting stock, use of antitranspirants, and after-planting care of trees). Some opportunities available to the plant breeder for producing drought-resistant trees are emphasized.

## DEVELOPMENT OF WATER DEFICITS

TREES ARE UNIQUELY WELL constructed to lose large amounts of water. They expose an extensive leaf area that is perforated by numerous stomatal pores through which water is readily lost by transpiration. Under appropriate environmental conditions (high soil moisture availability, high air temperature, and low relative humidity), a large tree may lose a barrel of water or more in a day. In fact, willows and cottonwoods along stream banks may absorb and transpire as much as 40 inches of water in one growing season *(Spurr 1964)*. Only a very small amount of the water absorbed by trees, probably less than 5 percent, is used in growth, and the rest of it merely goes through the tree and evaporates into the atmosphere. It has been estimated, for example, that plants may use 250 to 1,000 pounds of water to produce 1 pound of dry matter in growth of leaves, stems, roots, and reproductive tissues.

Because of their high rates of water loss, all trees, well-established as well as recently transplanted ones, undergo periodic internal water deficits of varying degree. Such water deficits are well known during developing droughts, but they also tend to develop regularly during the day even in trees growing in well-watered soils. This is so because internal water deficits in trees are controlled by relative rates of water loss by transpiration and replacement of water by absorption through the roots. During the day more water is lost by transpiration than is re-

placed by absorption. Hence, trees tend to dry out during the day, especially on hot, sunny days. During the night, however, both transpiration and absorption rates are low, but the rate of absorption is higher than the rate of transpiration, resulting in a gradual refilling of the tree with water. The rate of absorption of water by roots during the day lags behind transpiration because of resistance to water movement in various parts of its translocation path from the soil, through the tree, and outward into the air. Some resistance to water movement exists in the soil, in the roots, and in the leaves.

It is clear that dehydration of trees will result from high transpiration rates or slow absorption of water from dry, poorly aerated or cold soils or, more commonly, from both high transpiration and relatively low absorption rates. Transpiration and absorption of water are partly controlled by different sets of factors. Transpiration is largely controlled by atmospheric factors that influence evaporation (light, temperature, humidity, wind) as well as by such plant factors as leaf area, structure of leaves, stomatal size and frequency, and control of stomatal aperture. Absorption of water is controlled by transpiration rate and also by the size and distribution of the root system and various soil factors (soil water availability, temperature, concentration of the soil solution, aeration, etc.). Temporary water deficits and leaf-wilting often occur in the afternoon because of excess transpiration over absorption. This is not serious if the soil is well watered because the leaves rehydrate and recover turgidity at night when absorption exceeds transpiration. However, as soil dries over a period of days, temporary water deficits in trees tend to persist longer each successive day because leaves are less likely to recover turgidity at night *(Kramer and Kozlowski 1960; Kozlowski 1964, 1968a, 1968b, 1969, 1970)*.

## EFFECTS OF WATER DEFICITS ON TREES

Water deficits in trees affect virtually all important physiological processes, including stomatal closure, photosynthesis, metabolism, mineral relations, and growth.

### Stomatal Closure

The closure of stomatal pores is a very early response to drought. As the guard cells lose water and turgidity decreases, the stomatal pores close. The dehydration of trees is controlled somewhat by earlier closure of stomata during each day of a developing drought and by temporary closure of stomata during the day. However, closing stomata during a drought may not prevent killing of those trees that lose considerable water directly through the leaf epidermis after stomatal closure occurs.

After a drought, leaves may recover turgidity, and stomata may open. Nevertheless, severe droughts often damage many stomata, which may open slowly or not at all when a tree is finally rewatered. The stomata of shade leaves are more sensitive to water loss than those of sun leaves. Also, the stomata of young leaves tend to close faster than those of old leaves during drought *(Kozlowski 1972b)*.

### Photosynthesis

In many species photosynthesis begins to decrease when leaves are only slightly dehydrated. Such photosynthetic inhibition is caused first by stomatal closure causing decrease in $CO_2$ uptake and only much later by direct inhibitory effects on the photosynthetic mechanism *(Brix 1962, Troughton and Slatyer 1969 Slatyer 1973)*. Hence, we may expect simultaneous reduction in stomatal aperture and in photosynthesis as drought intensify, as well as midday dips in photosynthesis during periods of temporary stomatal closure.

### Wilting

As leaves dehydrate and lose water they eventually wilt. Wilting varies in degree and may be classified as: (1) incipient, (2) temporary, or (3) permanent. Incipient wilting does not cause drooping of leaves. Temporary wilting involves drooping of leaves during the day and recovery from wilting during the night. During a sustained drought, plants temporarily wilted may become permanently wilted. Such plants do not recover from wilting at night. Recovery from permanent wilting requires rewetting of the soil. Trees that stay in a state of permanent wilting for an extended period often die.

### Shoot Growth

Shoot formation of many trees is a 2-year process involving bud formation the first year and expansion into a shoot the following year. In many species (maples, ashes, and some pines) winter buds are telescoped shoots, which contain all the leaves that will be expanded in shoot growth during the next growing season. In such species annual shoot growth usually is completed relatively early in the frost-free season. Trees that have such fully preformed shoots in the winter bud often complete height growth in about a month or slightly longer. For example, the growth of red pine *(Pinus resinosa)* shoots in Wisconsin generally is completed by the end of June. Hence, this species completes most shoot growth before mid- and late-summer droughts occur. Its height growth often is better related to rainfall of the previous season than to current rainfall because, as mentioned, the shoots are morphologically determined in the bud laid down in the previous year. Current height growth represents only bud expansion and does not involve growth of new organs.

In contrast to species having fully preformed shoots in the winter bud and a short period of shoot expansion, other species have shoots that continue to elongate for a long time during the summer. In this second group are recurrently flushing pines of the southern United States and species that continue to form new leaves during the summer, in addition to expanding those that were in the winter bud. Recurrently flushing species produce several bursts of shoot growth each year, first from opening of the winter buds and later in the summer from new buds formed during the current year. Such species may continue shoot growth for several months in the Southern States. Their shoot growth is very responsive to mid-summer drought. But even in Northern States some trees, such as poplars, do not always have a fully preformed shoot in the winter bud. Such trees continue to produce new leaves during the summer, and their shoots continue to expand into late summer. Their shoot growth can be checked by midsummer droughts. This is in contrast to many northern species (ash, maple, red pine, etc.) whose total annual shoot growth is completed early—that is, before midsummer droughts occur *(Kozlowski 1971a)*.

### Cambial Growth

Growth in diameter of trees is particularly sensitive to water supply. During dry years trees produce narrow annual rings of wood. During a summer drought, cambial growth either slows or stops altogether, depending on severity of the drought; and it accelerates or begins again following rain or irrigation. Changes in cambial growth in response to dry and wet periods may cause formation of false or multiple rings of wood in stems. These often have been mistaken for annual rings.

Drought decreases the rate of diameter growth in trees not only in one year but also in the subsequent year or years. A summer drought affects the number of leaf initials that form in new buds for the shoots of the following year, and the consequent reduction in foliage reduces the amount of growth requirements (carbohydrates, hormones) that are translocated

downward and influence cambial growth *(Kozlowski 1971b)*.

### Reproductive Growth

Flowering and fruiting of trees are influenced by water supply at any stage during flower-bud formation, flowering, pollination, fertilization, embryo growth, or fruit and seed development. However, it is difficult to make broad generalizations about effects of drought on reproductive growth, partly because timing of the cycle of reproductive growth varies widely.

Formation of flower buds often is suppressed by drought, but the effect may not be obvious until the following year at flowering time. Sometimes, however, a mild water deficit at a critical time will increase initiation of flower buds by decreasing growth of vegetative tissues. Both the size and quality of fruits are improved by an adequate water supply before and during the period of fruit enlargement.

### Injury

Various tissues and organs of trees often are injured or killed by drought without necessarily killing the tree. Leaf responses to drought include curling, scorching, marginal browning, early autumn coloration, and premature leaf fall. Leaf drying often causes considerable winter injury to evergreens. During winter or early spring days, the air may warm and cause considerable transpiration at a time when water cannot be absorbed by roots from cold or frozen soil. This may cause the leaves to dry out and turn brown. If drought continues, the injury to the plant may occur in dieback of twigs and branches. Following prolonged and severe droughts, stems may become so desiccated that they crack. Drought cracks may or may not heal and, if they do not, they provide openings for invasion by decay fungi and insects.

Drought injury can be avoided or decreased in two ways: (1) by selecting and breeding trees for specific characters which induce drought resistance, and (2) by intelligent handling of available planting stock prior to, during, and after transplanting.

## DROUGHT RESISTANCE

Central to tree improvement and selection criteria for drought resistance is a consideration of inter- and intraspecific variation in characters that enables some trees to grow better than others under conditions of aridity. At the outset it should be emphasized that although both drought *avoidance* and *desiccation tolerance* (capacity of protoplasm to withstand severe desiccation) are involved in overall drought resistance, drought *avoidance* is much more important in enabling trees to survive under conditions of aridity *(Kozlowski and Davies 1975)*.

### Drought Avoidance

Many drought-avoiding adaptations occur in certain trees and may be found in leaves, stems, or roots. Drought avoidance by a tree often involves more than one adaptation. Furthermore, adaptations for drought avoidance often vary for different species of trees growing side by side. Among the important adaptations for drought avoidance are shedding of leaves; production of small or only few leaves; small, few, and sunken stomata; rapid closure of stomata during drought; thick leaf waxes; and strong development of palisade mesophyll. Although the volume of intercellular spaces often is less in xeromorphic than in mesomorphic leaves, the ratio between the internal exposed surface of the leaf and its external surface area usually is higher in xeromorphic leaves *(Fahn 1964)*. Stem adaptations for drought avoidance include capacity for twig and stem photosynthesis, presence of living wood fibers *(Fahn 1964)*, and development of a wide cortex that protects vascular tissues from desiccation. The most important drought-avoiding adaptations of roots are capacity

for extensive root growth (high root-shoot ratios), high root regenerating potential immediately after transplanting, and production of adventitious roots near the soil surface. Some of the most important drought-avoiding adaptations will be discussed briefly.

*Stomatal diffusion resistance.* — The amount of resistance to water loss from leaves varies among species and genetic materials because of variations in stomatal size, stomatal frequency, and capacity for rapid stomatal closure during developing droughts. In many species stomatal size and frequency are negatively correlated. For example, whereas *Acer saccharum* and *A. saccharinum* had many small stomata, *Ginkgo biloba*, *Betula papyrifera*, and *Gleditsia triacanthos* had relatively few large stomata. Stomatal size and frequency among different species of the same genus may also vary greatly, as in species of *Quercus*, *Fraxinus*, and *Crataegus (Davies et al., 1973)*. Differences in stomatal size and distribution among *Populus* clones have also been demonstrated *(Siwecki and Kozlowski 1973)*.

Variations among species and genetic materials in capacity for early stomatal closure are commonly much more important in drought avoidance than are differences in stomatal size or frequency. Examples of woody plants that avoid drought largely by rapid stomatal closure include plants of the Mediterranean maqui *(Oppenheimer 1953)*, *Ilex cornuta (Kaul and Kramer 1965)*, and *Eucalyptus sideroxylon (Quraishi and Kramer 1970)*.

We found that transpiration rates differed greatly among *Populus* clones and were better related to variations in stomatal aperture than to stomatal size and frequency or to such aspects of leaf anatomy as leaf thickness, epidermal thickness, amount of palisade parenchyma, amount of spongy parenchyma, percentage of combined thickness of spongy mesophyll plus epidermal layers, or percentage of palisade parenchyma *(Siwecki and Kozlowski 1973)*.

Wide variations occur among species in stomatal responses to atmospheric factors (for example, high temperature, high light intensity, low humidity, and wind) which induce water deficits in trees *(Davies and Kozlowski 1974a, Davies et al. 1974b)*. For example, experiments were conducted on species that occur along an ecological gradient from xeric to mesic. These included *Quercus macrocarpa*, *Q. velutina*, *Q. alba*, *Q. rubra*, and *Acer saccharum (Wuenscher and Kozlowski 1971a)*. All species showed an increase in transpiration with increased leaf temperature. The rate of increase of transpiration resistance with rise in leaf temperature was greatest for *Q. velutina*, intermediate for *Q. macrocarpa* and *Q. rubra*, and least for *Q. alba* and *Acer saccharum*. Water use efficiency (the ratio of transpiration to photosynthesis) increased with leaf temperature up to 35°C and decreased at higher temperatures. Water use efficiency was greatest in *Quercus velutina*, intermediate in *Q. macrocarpa*, *Q. rubra*, and *Q. alba*, and least in *Acer saccharum*. At 40°C, water use efficiency of *Q. velutina* declined only slightly, but in the other four species it decreased greatly. These experiments showed that stomatal resistance decreased along the gradient from xerophytic to mesophytic species. In particular it emphasized that *Q. velutina* had the highest water-use efficiency and was the most drought-resistant species studied. It fixed $CO_2$ rapidly while losing little water and therefore was successful on hot and dry sites *(Wuenscher and Kozlowski 1971b)*.

We have evidence from work with herbaceous plants that there is a genetic component in control of stomatal aperture. For example, rapid wilting and desiccation injury in abnormal diploid potato plants and wilty mutants of tomato were associated with lack of capacity for stomatal closure *(Waggoner and Simmonds 1966, Tal 1966)*. Failure of wilty mutants of tomato to close stomata was associated with a deficiency of abscisic acid *(Tal and Imber 1970, 1972)*.

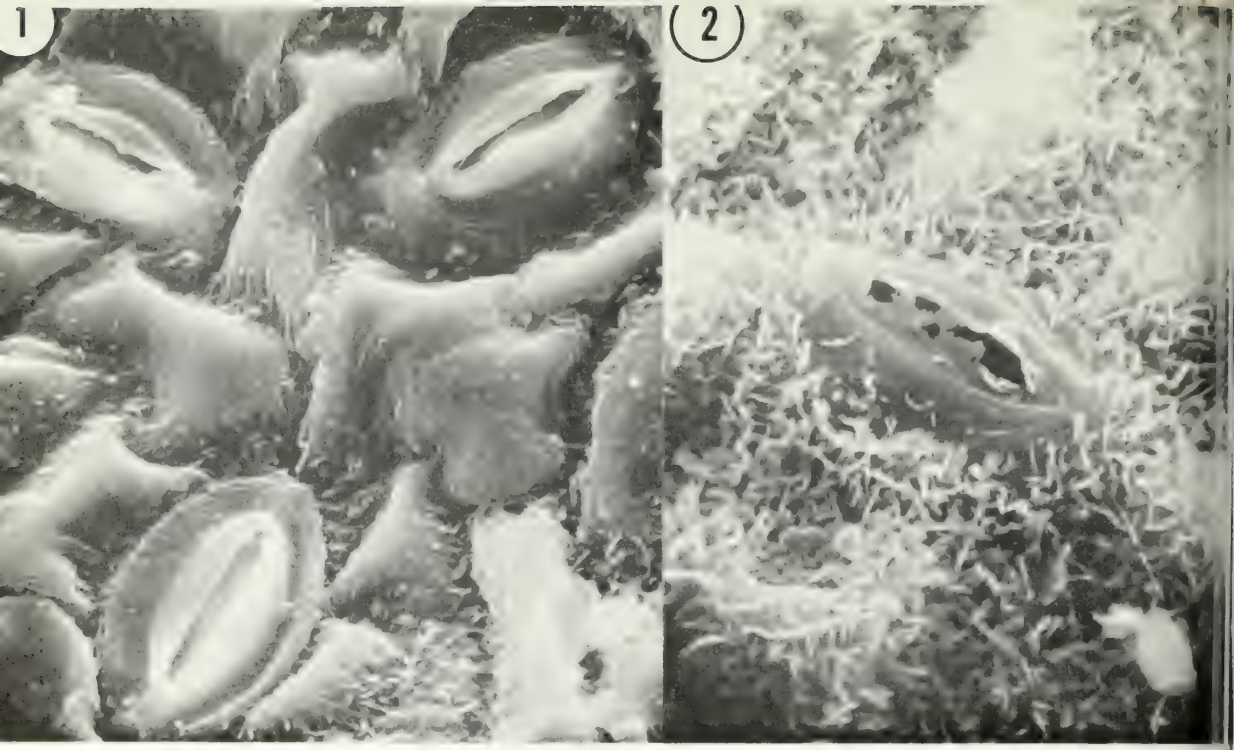



Figure 1.—Scanning electron micrographs showing leaf waxes around stomatal pores. Left: Betula papyrifera (x 1000). Right: Cercis canadensis (x 2000). Photos by W. J. Davies.

*Leaf waxes.*—After stomata close, cuticular control of water is an important factor in drought avoidance. For example, transpiration rates of drought-evading plants with closed stomata often vary from 2 to 20 percent of the rates when stomata are open. On the other hand, mesophytes with closed stomata generally lose from 20 to 50 percent as much water as they do with open stomata, emphasizing the importance of leaf waxes in water retention.

Our studies have shown wide variations among species in deposition of leaf waxes (fig. 1). *Fraxinus americana* leaves had cuticular lips overlapping large open stomatal pores, and they had thin leaf waxes. *Acer saccharum* leaves not only had a thick deposition of wax, but many stomatal pores were occluded with wax *(Kozlowski et al. 1974; Davies and Kozlowski 1974a)*.

Gymnosperms also vary greatly in amount of leaf waxes *(Hanover and Reicosky 1971, Lehala et al. 1972)*. For example, cutin layers were thin in *Thuja orientalis*, somewhat thicker in *Cupressus sempervirens*, and very thick in *Cupressus glabra (Oppenheimer 1970)*. Needles of *Pinus sylvestris* had more wax than those of *P. radiata (Leyton and Juniper 1963, Leyton and Armitage 1968)*. Oppenheimer and Shomer-Ilan *(1963)* demonstrated much better control of cuticular transpiration in *Pinus halepensis* than in *Pinus pinea*.

Pine needles have a stomatal antechamber that increases the length of the diffusion path for water and carbon dioxide. These antechambers often are occluded with wax *(Davies et al. 1974a)*, thus increasing the tortuosity of the pathway and decreasing the cross-sectional area available for diffusion. The antechamber waxes often are more important than leaf-surface waxes in control of transpirational water loss. For example, it has been estimated that wax in stomatal antechambers of *Picea sitchensis* reduced transpiration by about two-thirds when the stomata were open *(Jeffree et al. 1971)*.

In addition to environmental control of deposition of leaf waxes, genetic control also occurs with "normal" or glaucous forms being dominant and "glossy" or glabrous forms recessive. The differences in leaf appearance are due to variations in amount and structure of epicuticular wax *(Hall et al. 1965)*. In some species at least, adaptive changes in leaf waxes occur in response to selection by some ecological variable *(Harland 1947, Barber 1955)*. In Tasmania, for example, clinal analysis of glaucousness in several *Eucalyptus* species indicated high selective coefficients for genes controlling this characteristic. Nonglaucous (green) phenotypes were found in sheltered habitats, whereas glaucous phenotypes were increasingly common in more exposed environments *(Barber and Jackson 1957)*.

*Root growth.*—Because water in soil not penetrated by roots is largely unavailable to plants, trees with deeply penetrating and branching root systems absorb water most efficiently and prevent or postpone drought injury *(Kozlowski 1972a)*. There are many examples of the importance of a high root-shoot ratio (for example, relatively high water-absorbing capacity and relatively low transpiration capacity) to survival of trees under drought conditions. For example, on dry sites *Eucalyptus socialis* outcompeted *E. incrassata* partly because of the higher root-shoot ratios and slower growth of aerial parts, thus preventing desiccation *(Parsons 1969)*. Deep rooting also is an important factor in drought avoidance of several species of Western Australian sclerophylls *(Grieve and Hellmuth 1970)*. Woods *(1959)* attributed the high degree of success of *Pinus caribaea* trees on dry sites to initiation of root growth soon after transplanting.

In studying genetic variations in root-shoot ratios, it is vital to recognize that these change with plant age and weight according to the law of allometric growth. Ledig and Perry *(1965)* emphasized that the genetic variations they found in root-shoot ratios of *Pinus taeda* progenies were due primarily to comparing seedlings of different weight.

A useful research approach may involve grafting scion stem pieces on clonal rootstocks. We know that rootstocks influence meristematic activity and tissue development as well as the morphogenetic potential of apical and lateral meristems in many genera of forest trees *(Tubbs 1967, 1973)*. In forestry the emphasis on use of rootstocks has been on wood production or early seed production for breeding. We need to extend such work toward achieving drought avoidance through altered root-shoot balance. It seems highly relevant that dwarfing rootstocks or scions induce short laterals and spur shoots in some species, and in others they maintain an effective leaf area in the compound tree over a shorter season than do vigorous rootstocks or scions *(Tubbs 1967, 1973)*.

*Root regenerating potential.*—Wakeley *(1954)* demonstrated that critical internal physiological conditions of nursery stock that influenced root-regenerating potential after outplanting often were much more important to survival of trees than were morphological grades of transplants. He found, for example, that cultural practices in nurseries, especially differences in fertilizer regimes, greatly influenced survival. Matched plantings of trees from certain nurseries survived better than others regardless of season, site, and even species. In addition, he found marked variation in survival of outplanted seedlings that had been grown from the same seedlot but in different locations of the same nursery. High percentage of survival was correlated with high root-regenerating potential.

Planting of trees that show marked seasonal periodicity in root-regenerating potential should be limited to the time of year when high capacity for root growth occurs. On sites with high availability of soil moisture, adjustment of planting schedules is less important *(Kozlowski 1971b)*.

Particular attention is called to the

useful physiological grading system of Stone and Jenkinson *(1971)* for pine nursery stock in California, based on expected root growth after planting. They demonstrated that root-growth capacity could be predicted once nursery cultural practices were standardized and the nursery climate was characterized. The system involved: (1) monthly tests of root-growth capacity of seedlings lifted before and during the lifting and shipping season, and (2) a cumulative record of the number of hours that air temperatures in the nursery were below 10°C.

Root-regenerating potential varies with nursery cultural practices, nursery climate, and cold storage. Fumigation, watering, fertilizing, and root-pruning practices differ from nursery to nursery, and they vary from year to year in the same nursery. For these reasons plants from different nurseries may differ widely in root-regenerating potential. Hence cultural practices should be standardized before root-growth capacity can be predicted.

Climate also controls seasonal periodicity in root-growth capacity. Thus, if the nursery climate varies greatly from year to year, the date on which root-growth capacity reaches its peak will also vary. A shift in peak of root-growth capacity is controlled largely by the number of hours that seedings in the nursery are exposed to low air temperatures. For example, in a California nursery, a minimum exposure of 1,500 hours of air temperature equal to or less than 10°C was required before the peak was reached.

When normal nursery practice involves 2 to 4 months of seedling cold storage after lifting, the effect of cold storage on root-growth capacity can be evaluated in the same way as for newly lifted seedlings. The effect of cold storage depends on when the seedlings are lifted in the nursery. In California, root-growth capacity was reduced by cold storage if seedlings were lifted in the early autumn, increased by cold storage if the seedlings were lifted during early winter when the build-up in root-growth capacity was under way, and reduced if the seedlings were lifted during or after root-growth capacity peaks.

*Root pruning.*—Trees in the nursery can be conditioned to withstand transplanting by root-pruning them every few years. This will confine the absorbing roots to a small area, thus causing minimal injury during lifting. Since root-pruning also stimulates growth of many small absorbing roots, it leads to efficient water absorption by transplants. By comparison, large trees in the field, which have long roots, do not transplant readily because most of their absorbing roots are lost during lifting.

*Shedding of leaves.*—Leaf-shedding during drought is one of the most important drought-avoiding adaptations of trees in arid regions. For example in the "Caatinga" and "Cerrado" of Brazil the leaves of many species are shed at the height of the rainless season *(Ferri 1953, 1961, Eiten 1972)*. In southern California *Encelia farinosa* is without leaves during the dry season. A rain induces emergence of a new crop of leaves. These expand, and their final structure depends on how much water is available for cell expansion. As soil moisture supplies are depleted, the leaves developing higher on the branch have a denser structure than lower leaves. Finally, as water stresses increase, the leaves of lower density (those lower on the branch) develop higher water deficits than upper leaves, and the former are shed first *(Cunningham and Strain 1969)*. *Larrea tridentata* and *Fouquieria splendens* also drop their leaves during drought. *Fouquieria* rapidly grows new leaves after a rain, sometimes producing four or five crops in a year.

Reduction of transpiring surface by leaf-shedding is considered to be the most important adaptation for survival of desert plants in the Near East *(Orshansky 1954)*. There a number of plants reduce the weight of their shoots through abscission by amounts varying from a third to more than three-fourths. The

patterns of shedding vary among plants; seasonal dimorphism is attained by shedding and growth of various types of branches and leaves at different seasons. Leaves may be replaced by brachyblasts, reduced to stipules, or shed. Large winter leaves of some species are often replaced by small summer leaves *(Orshan 1972)*.

### Desiccation Tolerance

Although drought avoidance has been emphasized here, some woody plants of desert regions do have the capacity to tolerate extreme desiccation without injury to protoplasm. For example, *Acacia aneura* of Australia shows marked resistance to desiccation. It persists in regions that may have no precipitation for three consecutive months *(Slatyer 1961)*. Another example is *Larrea divaricata* of warm North American deserts. This relatively shallow-rooted plant also has high protoplasmic tolerance to desiccation and maintains net photosynthesis throughout extended periods of drought *(Odening et al. 1974)*. Mechanisms of protoplasmic drought tolerance are not completely understood and more research is needed on this important problem.

## TRANSPLANTING PRACTICES

In transplanting trees it is important to work toward decreasing transpiration, increasing water absorption, or preferably both. These objectives can be approached by attention to careful selection of trees, time of transplanting, site preparation, use of antitranspirants, and careful supervision of handling of planting stock before, during, and after transplanting *(Kozlowski and Davies 1975)*.

### Time of Transplanting

Trees are best transplanted when water loss by transpiration is likely to be low. Deciduous trees are best moved in the autumn after the leaves fall and before the soil is frozen, or in early spring after the soil has thawed and before buds open. It is best to plant in the spring in areas where the soil freezes deeply, where winds are strong, or where soil water supplies are low. Some trees with roots that are easily injured (for example, species of *Cornus, Magnolia, Liriodendron,* and *Cladrastis)* are best planted in the spring. Other trees recommended for spring planting are *Carya, Fagus, Liquidambar,* and *Juglans nigra (Pirone 1972)*. It cannot be emphasized too strongly that the danger of losing growth or of killing trees by desiccation increases greatly as transplanting is postponed from spring into summer. The increasing danger results from (1) expansion of leaves, increasing transpirational water loss, and (2) increasing transpiration because of more favorable environmental conditions for evaporation of water (for example, increase in temperature, causing steepening of vapor-pressure gradient between the leaves and air).

In warm regions, conifers can be transplanted any time, but they should be watered regularly. Broadleaved evergreens, such as *Magnolia* and *Ilex,* are best planted in the spring. However, they can be planted in the fall provided that ample time is available for resumption of root growth before the soil freezes.

In cold regions conifers can be planted early in the fall or in the spring after the soil has thawed. Container-grown and balled and burlapped conifers can be planted anytime the soil can be worked. These plants should be mulched and irrigated after they are reset in the ground

### Pruning of Shoots

The low absorbing capacity of roots can be dealt with by reducing transpirational capacity by pruning 15 to 40 percent of the bud-bearing branches. The extent of pruning should depend on the condition of the tree and the care it will receive after it is moved. Large trees require more pruning than small ones, and bare-rooted trees require more pruning than trees in containers or balled and burlapped trees. In fact, many containerized or balled and burlapped trees, espe-

cially evergreens, often do not require any pruning. Only secondary branches should be removed so as not to alter the shape of the tree.

### Site Preparation

Trees planted in heavy or poorly drained soil do not grow well. Hence, heavy soil should be replaced with topsoil, and other steps should be taken to assure good drainage.

Soil aeration is adversely influenced by flooding, compaction, trampling, sidewalks and pavements, and increasing grade around a tree and by heavy soils. Aeration is often a problem in clay soils because most of the pores are too small for water to drain properly. Such soils hold little air, and movement of air between the soil and atmosphere is slow. By comparison, aeration problems seldom occur in sandy soils because such soils contain considerable air, drain rapidly, and allow for movement of gases. The air capacity of heavy soils can be increased by adding organic matter, cinders, or sand.

Effects of poor soil aeration, whatever the cause, include a decrease in permeability of roots to water, causing decrease in absorption of water. Root respiration becomes anaerobic, at least in part. Since absorption of minerals requires energy released in respiration, mineral uptake is reduced by lack of oxygen in poorly aerated soils. These changes in physiological processes eventually lead to chlorosis and shedding of leaves, decreased shoot and cambial growth, death of twigs and branches, and death of trees.

### Handling of Planting Stock

All the work that goes into producing plantable trees can be rapidly undone by improper handling of nursery stock. Culling of nursery stock with low potential for survival is desirable. Beyond this, close supervision is needed during transplanting to be sure that nursery plants do not dry out to critical levels. Use of polyethylene packaging is helpful in conserving moisture of planting stock.

The chances of losing trees are much greater if they are moved with bare roots then with a ball of soil. Container-grown trees generally transplant better than balled and burlapped ones. Exposure of bare-rooted trees to drying for even a short time may have serious effects on growth and survival, but this varies with species and with the physiological condition of the plants at the time they are exposed. In one experiment, exposure of nursery stock for as little as 4 minutes reduced survival *(Hermann 1962)*. In another experiment, Hermann *(1964)* exposed 2 + 0 *Pseudotsuga menziesii* seedlings at 90°F and 30 percent relative humidity for periods up to 120 minutes. Survival by November of the year of outplanting was decreased with each added length of exposure. Exposures of 30 minutes influenced small seedlings more adversely than large seedlings, but size of plants was unimportant; and survival of both sizes was very low following exposure of 30 minutes or more.

Critical limits of exposure varied considerably with the physiological condition of the nursery stock. Seedlings lifted in the autumn could not survive more than a few minutes of exposure while those lifted in the winter survived exposure up to 30 minutes. These differences probably were related to root-regenerating potential. Prolonged storage also increased susceptibility to exposure. The importance of keeping exposure to a minimum was amply demonstrated. Even if long exposures did not reduce survival, they caused slow growth of seedlings.

Dipping of roots in compounds such as Agricol or Alginure also seems to have a favorable effect on absorption and water balance of transplants. Our data showed that dipping of *Pinus resinosa* roots in Alginure before transplanting increased survival and decreased the shock of transplanting. Dipping of roots in Agricol also has been useful in keeping bare-rooted plants fresh during storage and transport.

W. Tranquillini in Austria (personal communication) found that in plants treated with Alginure or Agricol the new roots dried out less, regenerated faster, and gained faster contact with soil after transplanting. Best results were achieved with Agricol.

### Antitranspirants

Antitranspirants (antidesiccants) are of two kinds: (1) film type, which forms a film over the leaf surface and physically blocks transpiration; and (2) metabolic type, which induces stomatal closure and thereby reduces transpirational water loss.

Antitranspirants have sometimes been used to good advantage *(Davenport et al. 1971)*. However, they also have injured or killed trees. Hence considerable skill and caution are needed in use of these compounds.

Although many antitranspirants effectively reduce water loss, they may be toxic. Toxicity is influenced by many factors, including the compound used, dosage, species to which applied, environmental conditions for some time after application, and method of application. We have found that some film-type antitranspirants reduced photosynthesis; altered metabolism; and caused chlorosis, leaf lesions, leaf fall, and reduced growth. Eventually some treated trees were killed *(Lee and Kozlowski 1974, Davies and Kozlowski 1974b, Olofinboba et al. 1974)*. Under certain conditions metabolic antitranspirants also may be very toxic *(Kozlowski and Clausen 1970)*.

Toxicity sometimes occurred early and, at other times, late. Toxicity was much greater at higher than at low temperatures. Toxicity also varied with method of application. It was much lower when antitranspirants were applied as sprays than when applied as leaf dips. For these reasons it is emphasized that, if used, antitranspirants should be applied to a few trees in a pilot experiment before they are applied to a whole population of trees. And on individual trees antitranspirants should be applied conservatively at low dosages to only some of the leaves so if these are injured other leaves will be available to carry on the photosynthetic function.

### After-Planting Care

The bark of newly transplanted trees generally will benefit from wrapping with crepe paper or burlap to prevent drying and sunscald. Trees with a stem diameter greater than 1 inch should be braced to prevent swaying, which sometimes impedes absorption of water through breaking of the soil-root contact.

Trees should be thoroughly irrigated after planting and regularly thereafter for at least the first few critical years or longer to insure that soil water deficit will not be an added barrier to maintaining a favorable internal water balance. Irrigation to a depth of 15 inches is advisable at approximately weekly intervals in well drained soils, or less often in tight soils.

Light waterings, which wet only the surface soil, are often wasted as the water evaporates rapidly from the soil surface and is not absorbed by deep-rooted trees. Watering should not be continued into late autumn in northern areas of the country that are subject to early freezes, since this may prolong growth and not give the tree enough time to harden.

Mulching of transplanted trees is beneficial in conserving soil moisture and stabilizing temperature. Trees planted in the autumn should be mulched when planted. Those planted in the spring should be mulched after the soil warms. Suitable mulches include peat moss, leaf mold, pine needles, ground cobs, and straw *(May 1972)*.

## THE CHALLENGE TO TREE BREEDERS

Much can be done in the short term with cultural practices to control water loss of transplants. Such improved practices should always dominate the think-

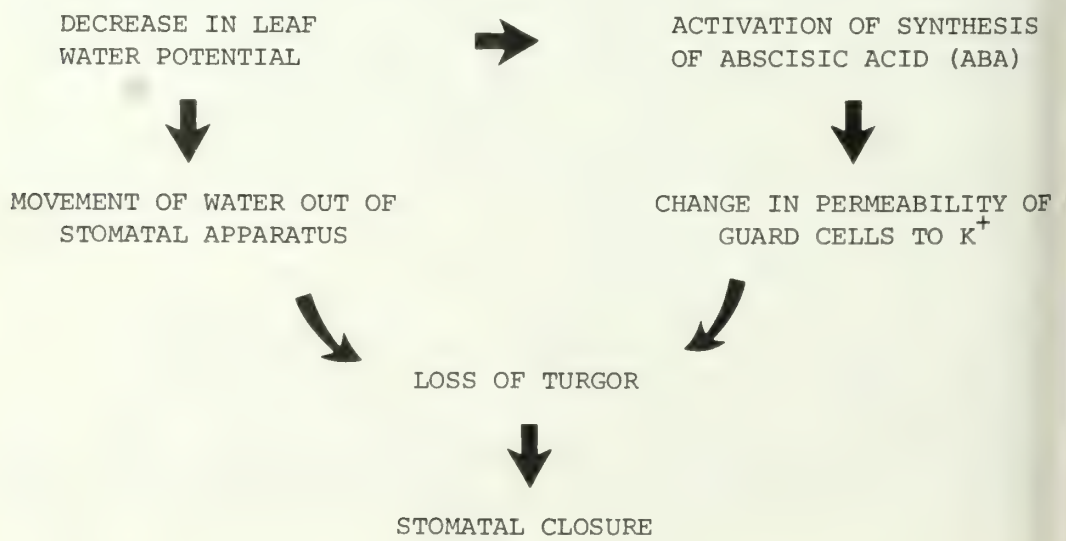
ing of arborists. In the long term, and especially in arid regions, the tree breeder can contribute toward improving planting stock with respect to one or more drought-avoiding characters (high leaf diffusion resistance, abundant leaf waxes, early shedding of leaves during drought, small leaves, high root-shoot ratios, etc.). Overall drought resistance of trees generally represents an integrated response to various degrees of specific drought-avoiding adaptations. The relative contributions of drought-avoiding characters may be expected to vary both between and within species. Hence the breeder must assess the need for improving some characters more than others in his particular plant materials. It should also be remembered that some characters that contribute to drought avoidance, such as early stomatal closure and leaf shedding, will reduce photosynthesis as well as water loss. Therefore some growth must necessarily be sacrificed in favor of tree survival and decreased drought injury.

Drought avoidance might be increased by selection or breeding for small stomata, few stomata, and stomata that close early during drought. Because control of the stomatal apparatus is both sensitive and complicated, involving hydraulic components and hormonal ones (especially production of abscisic acid) (fig. 2), the tree breeder should work closely with plant physiologists. Control of water loss may also be achieved by working for early leaf-shedding during developing droughts. Such induction also involves important biochemical controls, through hormone and enzyme systems, of acceleration of the stimulus—signal—and response phases of abscission *(Osborne 1973.*

As shown with herbaceous plants, there is also possibility of improving water-use efficiency. According to Gardner *(1963)*, it is more important to breed for water-use efficiency within a species than among species. If genotypic variation for water-use efficiency is appreciable, advances might be made by a simple breeding method such as mass selection. However, if genotypic variation is small, progeny tests may be necessary.

Some species, such as *Acer saccharum*, have leaves with relatively high diffusion resistance (small stomata and abundant leaf wax) and low rate of transpiration

Figure 2.—Control of stomatal aperture by both hydraulic and hormonal systems (from Kriedemann and Loveys 1974).



per leaf *(Kozlowski et al. 1974)*. Yet they often are injured by drought when they develop very extensive leaf areas. In such species the possibility of decreasing crown size by use of dwarfing rootstocks might prove fruitful. These considerations point up some exciting opportunities available to the tree breeder for producing drought-resistant trees.

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# SOIL COMPACTION AND ITS EFFECTS UPON URBAN VEGETATION

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*ABSTRACT.* The urban environment imposes severe stress upon vegetation. The problems are many and interactions common, making simple solutions difficult. This paper on urban soils discusses the basic soil physics involved, reviews existing literature, and describes several research efforts in Washington. Particular emphasis is placed on soil compaction and ways to minimize its deleterious effects upon vegetation.

## NATURAL SOILS

SOILS AS THEY OCCUR NATURALLY provide the basis for a better understanding of urban soils. Of particular interest to our work are the physics and the major components of a soil.

Soils are very complex, naturally formed entities that vary widely with the natural landscape. The principal mineral fractions considered are three: sand, silt and clay. The sand fraction 2.0mm-0.05mm) is virtually chemically inert but does provide vital structural capabilities for the soil mantle and assists in reducing compaction. Silt (0.05mm-0.002mm) provides structural support as well as some minor contributions to fertility. The clay fraction (0.002mm and smaller) provides most of the nutrient or fertility capabilities and also supplies much of the matrix of soil structure and tilth.

These three fractions combined form roughly 45 percent of a hypothetical or "ideal" soil. The remaining 55 percent is composed of 5 percent organic matter (decaying and decayed plant parts, organisms, etc.), 25 percent for air space ($N_2$ forming 79.2 of the soil atmosphere, $O_2$ 20.6 percent and $CO_2$ 0.2 percent), and 25 percent for water or moisture capabilities. Organic matter assists the clay fraction in maintaining the soil structure and provides nutrient exchange and food for microorganisms. The organic matter and clay content can each affect soil fertility (nutrient status) and pH. Pore space, ideally composed of equal amounts of air and water space, fluctuates widely depending upon rainfall, humidity, temperature, compaction or use.

The preceding simplistic discussion of soil physics forms the background of our discussion of urban soils and compaction. I shall not discuss pH and fertility because these characteristics vary widely and, by and large, can be modified or altered on a site-by-site basis in the city.

In the National Park Service we are concerned with the carrying capacity for

an area or simply the number of visits an area can support without deterioration of the resource we are trying to conserve. Soils are the medium in which turf, ornamental shrubs, small trees, and large trees receive support, moisture, oxygen, and nutrients. The soil also helps protect the root systems from the adverse effects of overuse. The purpose of vegetation in the city is different from that of forestry and agriculture—we are primarily interested in vegetation for esthetic purposes, not food and fiber production.

## SOIL COMPACTION

In the areas of intense use, the soil parameter that seems to be the best single barometer of soil conditions is bulk density. Bulk density has been used as the index of compaction *(Pearson 1966)*. Bulk density is an expression of the mass per unit volume and can be an indicator of a wide variety of soil properties. Much has been accomplished to alleviate compaction in agricultural soils *(Barnes and others 1971)*, and one must begin with a review of this literature to better understand the basic principles involved.

Pore space, ideally 50 percent as mentioned previously, is the portion of the soil matrix that is directly and adversely affected by heavy use *(Cordell and James 1971)*. Pore-size distribution (the distribution of macro- and micropores) does not remain constant, but is altered by compaction, cultivation, aggregation, fertilization, etc. *(Waddington 1968)*.

Moisture retention or the available-moisture range is not a measure of total pore space, but does vary with soil texture. Generally sands and loamy sand have an available water range of 7.5 to 40 percent, moderate-textured soils of 10 to 18 percent, and clay loam to clayey soils of 11 to 14 percent *(Peterson and others 1968)*. Available-moisture range involves mostly micropores, plus a few of the smaller macropores. When all pores are filled with water, the soil is saturated. For simplification, pores losing their water at low tension can be considered macropores—which have been defined *(Franken 1969, Hartage and Bailly 1970)* as pores greater than 50 $\mu$.

Hartage *(1968)* indicated that good permeabilities for water and air occurred with a variety and continuity of pore space. Pores initially affected by compaction were the very large macropores, 150-50 $\mu$. Geisler *(1968)* indicated that, with a reduction of macropores, there is an increase in number of pores less than 10 $\mu$—pores that provide very low permeabilities for water and air.

Dimitriu *(1974)* suggested that, as bulk density increases, more of the movement of moisture occurs through the capillary or micropore space. Sololovskaya *(1967)* suggested that the wilting point of most soils is not affected by compaction. With compaction, the solid phase of the soil increases per unit volume, and therefore, the percentage of bound water (water unavailable for plant use) is increased. The change is most notable in loamy or medium-textured soils *(Ghildyal and Satyanarayana 1965)*.

Baver *(1972)* has indicated the need to maintain good soil structure and/or aggregation, and high infiltration rates. If this is accomplished, a desirable portion of pore space will result. Further, the aggregates within the soil profile can be used to indicate porosity. Aggregates which are angular in nature indicate fine internal porosity, while these which are rounded indicate moderate to coarse porosity.

Total pore space can be calculated when the bulk density (BD) and particle densities (PD) are known: $(100 - BD/PD) \times 100 =$ total percent pore space.

Van der Valk *(1971)* has suggested that when the percent total pore space is less than 44 percent, the growth of flower bulbs can be impaired. When a reduction in the percentage of total pore space occurs, there is a rapid decline in the hydraulic conductivity of the soil *(Singh and Gupta 1971)*. Singh and Gupta suggested that the optimum bu

density for agricultural crops is 1.33 g/cc. As the bulk density increases, the maximum aeration decreases and becomes the most limiting factor to root elongation *(Baver 1972, Hopkins and Patrick 1969)*. Root elongation and root penetration into soils of high bulk densities is restricted to the naturally occurring cracks rather than within the soil matrix *(Worker 1973)*. As bulk density of the soil increases, a very significant reduction occurs in the weight of roots, stems and leaves of agricultural crops *(Berben 1972, Barley 1963 and others)*. In contrast, Johnston and Wood *(1971)* noticed no significant reduction in sugar cane yield because of soil compaction. However, sugar cane is an exception. Vigor of most plants suffers under soil compaction.

Richards *(1974)*, working with peach trees, Slowik *(1970)* with apple trees, and Hatchell *(1970)* with loblolly pine, noted a negative correlation between growth or plant vigor and increasing bulk densities. Richards *(1974)* went on to indicate that, when the compaction was severe enough to reduce air space to less than 15 percent, root growth was restricted; and less than 2 percent air space resulted in essentially no root growth. Bakker and Hidding *(1970)* indicated that 20 percent air space was needed for adequate gaseous exchange between the soil and the atmosphere. Burke and others *(1972)* noted an increase in disease incidence of agricultural crops due to compaction.

Some work has been done in an attempt to reduce the adverse effect of high bulk densities through application of gypsum *(Shabassy 1973, Scotter and Loveday 1966)*. Gypsum increases aggregation and porosity while reducing the bulk density of the surface soil. Some other treatments for reducing bulk density will be discussed later.

## SOIL PORE SPACE

Both soil atmosphere and water movement are directly affected by, and related to, soil compaction. In general terms there is a balance between the soil atmosphere and soil water. After a saturating rain, the soil pores are filled with water, leaving little pore space for soil gases. As water is lost to evaporation and percolation, the volume of soil gas increases. During very dry periods the gaseous phase predominates, and little water is available for plant use. Sekiguch *(1973)* noted that, for street trees, moisture depletion can occur rapidly and can vary widely from location to location.

According to Hady *(1974)*, Dasberg and Bakker *(1970)* and Youngberg *(1970)*, oxygen in the soil profile is the key to regulating plant growth. Youngberg indicated that, when the oxygen content of soil drops below 10 percent by volume, growth of Scotch pine and Norway spruce seedlings was drastically reduced. Lees *(1972)* concurred, reporting that when the oxygen concentration dropped below 10 percent, *Pinus contorta* growth was severely limited. He observed that oxygen was required for root extension in these plants. Similarly, containerized plantings commonly used in urban areas require adequate soil aeration.

Within the soil profile the principal movement of oxygen and carbon dioxide is through diffusion *(Wood and Greenwood 1971)*. Kays *(1974)* noted that an inverse relationship exists between concentrations of oxygen and carbon dioxide in the soil. In the surface soil, oxygen will generally predominant over carbon dioxide. With increased depth in the soil profile, the relationship is altered so that carbon dioxide begins to predominate over oxygen.

The gaseous phase of the soil occurs in three principal forms: (1) a free state that is found within the pores, (2) a dissolved state in which the gases are dissolved in water, and (3) an absorbed state—on the mineral and organic fractions *(Stolzy 1974)*. Stolzy concludes

that, if internal drainage is good, the oxygen content of the soil will rarely drop below 15 percent, while the carbon dioxide content is rarely above 5 or 6 percent.

Yelenosky *(1963, 1964)* found that, under poor aeration the oxygen concentration drops to as low as 1 percent, while the carbon dioxide content rises to 19 percent or higher. Soil aeration can be reduced by a layer of clay over existing soil, by compaction (as from heavy use), or by a paving operation. Under those treatments the soil atmosphere changes from aerobic to anaerobic, and the change can, seemingly, occur within a growing season. Once an area becomes compacted, re-creation of an aerobic soil condition is difficult. The relationships between soil compaction (or bulk density) and oxygen content upon root penetration are dramatic (fig. 1). Compaction and carbon dioxide have an equally dramatic effect upon root penetration (fig. 2).

Figure 1.—Effect of oxygen concentration and bulk density on depth of root penetration by cotton seedlings into compacted soil (after Tackett and Pearson 1964a, but reproduced from Plant Environment and Efficient Water Use with permission of the American Society of Agronomy).

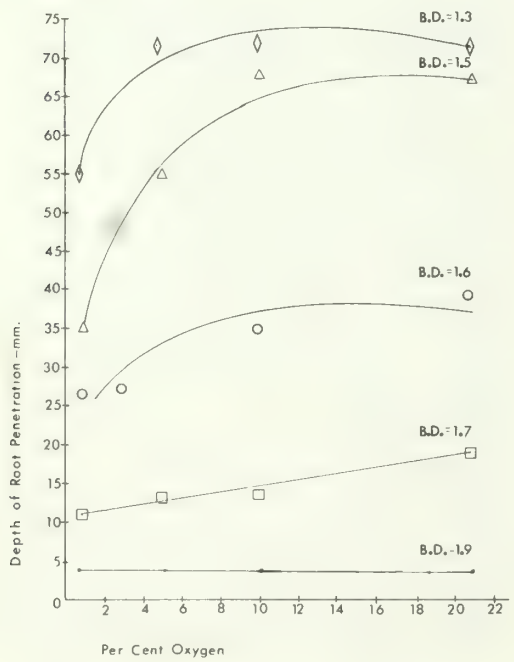
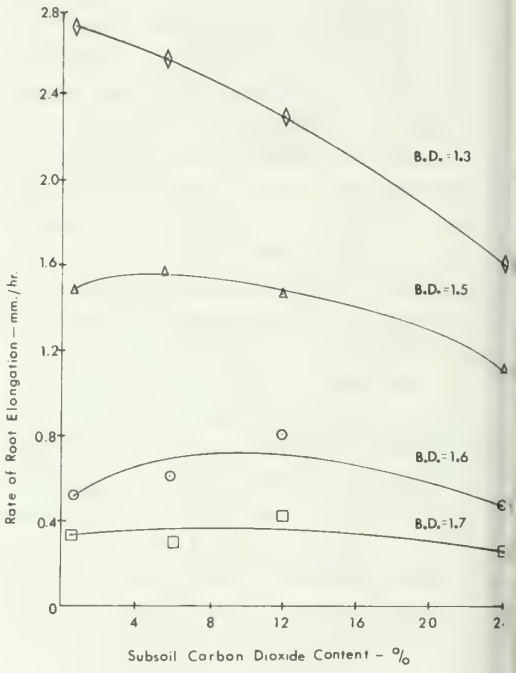



Figure 2.—Effect of carbon-dioxide level on rate of root penetration by cotton seedlings in compacted subsoil (after Tackett and Pearson 1964b, but reproduced from Plant Environment and Efficient Water Use with permission of the American Society of Agronomy).




There are means available to help re-create an aerobic soil atmosphere—although prevention of poor aeration by proper and adequate soil preparation has been most often emphasized *(Martin 1971, Hiler and others 1971, Grabert and Steinbrenner 1972)*. When a soil does become compacted, one of the most successful means to improve aeration is subsoiling *(Grabert and Steinbrenner 1972)*. This method is often very costly and, in the urban environment, difficult to perform except on large open areas. Where soils are poorly drained, the installation of tile drains may improve aeration. In areas that are difficult to drain, the use of plant species well adapted to moist conditions is advisable.

Pavements cause the soil atmosphere

to change from aerobic to anaerobic, thereby reducing the vigor of plants *(Yelenosky 1964, Franken 1969, Hartage and Bailly 1970, Hartage 1968)*. On the basis of observations in Washington, D.C., I believe that the soil beneath pavements is usually quite moist and the soil atmosphere is predominately anaerobic. Pirone *(1972)* stated that pavements prevent gaseous exchange with the atmosphere, and that a general anaerobic condition occurs beneath pavements. Normal gaseous exchange between the soil and the atmosphere is necessary for tree roots and microbes to respire. This exchange can be interrupted by pavements and compaction, thus retarding root growth essential to tree vigor.

I found limited information on the topic of species tolerance to soil compaction. Yelenosky *(1964)* reported that, of seven species of seedlings, American elm was the most tolerant to poor soil aeration, while the tuliptree (yellow-poplar) seedlings were the least tolerant. Littleleaf linden, 'Moraine' honeylocust, white oak, sugar maple, and flowering dogwood were intermediate between American elm and tuliptree. Pirone *(1972)*—as reported by Kozlowski and Davies *(1975)*—listed species affected by poor soil aeration, as follows: (1) most severely injured: sugar maple, beech, dogwood, oak, tuliptree, pines, and spruce; (2) less severely injured: birch, hickory, and hemlock; and (3) least injured: elm, poplar, willow, plane, pin oak, and locust. The two authors do not wholly agree in rating the susceptibility of various species.

Soil compaction and anaerobic conditions caused by paving, heavy use or flooding do cause an unfavorable rooting environment for most trees. Differences apparently exist in the tolerance of tree species and of individuals within species to compacted conditions within the urban environment. Plants most suited to such conditions have apparently undergone some selection simply through survival of stems of adapted species. However, much research still needs to be done as a basis for selecting suitable species or cultivars.

Of possible research approaches, one would be to create variable soil conditions and to grow a variety of trees there. Another approach would be to study the effects of flooding—either through observations of flooded areas or through creation of controlled conditions. Several authors, as Bell *(1974)*, have used the former method, and a few as Hosner *(1960)* used the latter. Resulting lists of tolerance to flooding do vary:

*Bell*

Intolerant:
- black oak
- black cherry
- sassafras

Slightly tolerant:
- redbud
- black walnut
- shingle oak
- shagbark hickory
- hackberry
- American elm
- green ash

Tolerant:
- silver maple
- sycamore
- black willow
- bur oak
- honeylocust
- boxelder
- swamp white oak
- pin oak
- eastern cottonwood

*Hosner*

Least to most tolerant:
- cherrybark oak
- hackberry
- sweetgum
- shumard oak
- red maple
- sycamore
- pin oak
- American elm
- green ash
- eastern cottonwood
- black willow
- boxelder
- silver maple

Differences in such lists may be due to several factors, such as season of the year, age and vigor of component trees, and duration of flooding. For example, McAlpine *(1961)* reported that in a controlled study, tuliptree seedlings were not adversely affected by flooding for 14 days during the dormant season, but mortality occurred after 4 days of flooding in May or 3 days in June. In contrast, green ash and sweetgum seedlings were not affected by up to 14 days of flooding during any month, and the flooding seemed beneficial rather than detrimental to their growth.

Plants vary widely in their ability to withstand extremes of soil aeration and soil moisture. Chaplin *(1974)* indicated that cherry and peach trees succumb quickly to excess soil moisture. Plants do possess built-in mechanisms (stomata) that control flow of moisture through their leaves *(Kozlowski 1972a, 1972b)*. However, these mechanisms are not capable of handling excess amounts of soil moisture.

In some urban areas natural gas can cause plant stress. This topic will not be discussed here, and the reader is referred to the literature *(Groth 1971, Davis 1972, Walton 1972/73)*.

Water is vital either directly or indirectly in nearly every process occurring in plants, and its proper management is difficult to assess. Yelenosky's *(1964)* summation of soil and plant relationships was succinctly stated: "there are no simple answers to meet all situations concerning tree growth and soil aeration." This seems to be the case within the urban ecosystem.

## SOIL COMPACTION IN WASHINGTON, D.C.

Tijmens *(1973)* indicated that planting should be an integral part of urban planning, and I believe that this is the direction we are all working toward.

Plants in urban areas exist under a myriad of environmental stresses and those in Washington are no exception. When you consider the effects of soil compaction, insects, disease, drainage, water pollution, deicing salt, and vandalism, which individually can reduce or prohibit tree growth, it is not surprising that their synergistic effects are quite severe *(Seibert 1973 and others)*.

### Determining Present Conditions

The soils program at the Ecological Services Laboratory of National Capital Parks has focused on soil heterogeneity, compaction and related physical properties, and to a lesser extent on the chemical properties. One significant endeavor has been a comprehensive survey of Washington's soils in cooperation with the Soil Conservation Service. This survey, the first comprehensive survey of urban soils, is nearly 90 percent completed (the field mapping is completed). It will be an exceptionally valuable aid in planning and planting for Washington's plant scientists and urban planners.

Prior to the soil survey we did some soil-characterization work on the Mall. The first urban-soil profile I observed was dramatic. A distinct characteristic was realized with every swing of the pick, that of severe density or compaction. Analyses have been completed for that profile and for three others on the Mall table 1). Data on bulk density and pore space in these samples verified the inadequate pore space for moisture and air exchange. Ideally the bulk density should range between 1.3 and 1.6 g/cc, while the pore space should range between 40 and 45 percent. For the Mall soils, the bulk density range was 1.7 to 2.2 g/cc, while pore space was 13 to 36 percent.

I conducted a small experiment to determine if in fact "urban soils are as dense as concrete." Four commonly used construction materials were tested: cinder block, brick, asphalt, and concrete. The data (table 2) reveal that our urban soils are indeed as "dense as concrete" (The range in bulk density of brick is attributed to differing manufacturing tech

Table 1.—Density and pore space in the horizons of four soil pits of the Mall

| Location and horizons | | Number of samples | Bulk density | | Particle density | Calculated pore space[1] |
|---|---|---|---|---|---|---|
| | | | Range | Average | | |
| 7th & Washington Dr. | | | *g/cc* | *g/cc* | *g/cc* | *Percent* |
| Pit I: | A1 | 5 | 2.01-2.14 | 2.12 | 2.56 | 17.2 |
| | C1 | 5 | 1.77-1.97 | 1.81 | 2.65 | 31.7 |
| | IIC2 | 5 | 1.88-2.20 | 2.02 | 2.54 | 20.5 |
| | IIIC3 | 5 | 1.90-2.02 | 1.95 | 2.54 | 23.2 |
| | IVC4 | 5 | 1.98-2.13 | 2.08 | 2.59 | 19.7 |
| Pit II: | Ap | 6 | 2.02-2.22 | 2.18 | 2.51 | 13.1 |
| | A2 | 6 | 1.69-1.97 | 1.90 | 2.58 | 36.4 |
| | C11 | 6 | 1.67-1.88 | 1.81 | 2.53 | 28.4 |
| | C12 | 6 | 1.67-1.71 | 1.70 | 2.48 | 31.4 |
| Pit III: | Ap | 5 | 1.96-2.13 | 2.08 | 2.40 | 13.3 |
| | C1 | 5 | 1.76-2.06 | 1.81 | 2.47 | 26.7 |
| | IIC2 | 5 | 1.82-2.00 | 1.90 | 2.50 | 24.0 |
| | IIIC3 | 5 | 1.96-2.01 | 2.00 | 2.56 | 21.9 |
| Washington Monument Grounds | | | | | | |
| | C12 | 3 | 1.80-1.82 | 1.81 | 2.47 | 26.7 |
| | C13 | 3 | 1.71-1.76 | 1.74 | 2.58 | 32.6 |
| | IIC3 | 3 | 1.79-1.94 | 1.87 | 2.41 | 22.4 |

[1] Pore space was calculated by the following formula: $(1 - \frac{\text{bulk density}}{\text{particle density}})\ 100 = \%$ pore space.

Table 2.—Bulk density and pore space of four construction materials

| Material | Number of samples | Bulk density | | Particle density | Calculated pore space |
|---|---|---|---|---|---|
| | | Average | Range | | |
| | | *g/cc* | *g/cc* | *g/cc* | *Percent* |
| Cinder block | 3 | 1.67-1.71 | 1.70 | 2.64 | 35.6 |
| Brick | 3 | 1.43-2.01 | 1.75 | 2.72 | 35.7 |
| Asphalt | 3 | 2.17-2.22 | 2.19 | 2.35 | 6.8 |
| Concrete | 3 | 2.23-2.27 | 2.26 | 2.47 | 8.5 |

niques—as different clays and firing methods.)

A high bulk density and low amount of pore space seem to exist in most of the soils examined and probably form the most restrictive characteristic of urban soils for plant growth. Other characteristics I have observed as common in urban soils are extreme heterogeneity from area to area, variability in percentages of organic matter with profile depth, unoriented coarse fragments (rock and stones), highly variable fertility and pH, a wide variation in textural distribution (percent of sand, silt and clay) with depth of profile, and a tendency for the compacted soils to repel moisture or exhibit a hydrophobic nature.

## Improving Present Conditions

Part of the soils work is directed toward finding economical ways to alleviate deleterious effects of soil compaction upon plants. Major areas needing renovation are heavily used: playgrounds, picnic sites, concession areas, athletic centers, etc. Soils of these areas undergo severe compaction that in all likelihood reduces the longevity of vegetation, particularly trees. A soil-amending process should assist in reducing compaction over the long term, 5 to 10 years or longer.

However, soil renovation is difficult once trees are established—because of the predominance of roots in the surface $A_1$ and $A_2$ soil horizons *(Howe 1974, Coile 1937, Hopkins and Donahue 1939, Scully 1942, and others)*.

At Hains Point, plots have been laid out under conditions of very heavy use in a picnic-playground area. The number of daily visits to the area is estimated at 800, and visitors are permitted unrestricted use of the area. The Park Service staff maintains the grounds as a part of their regular duties.

Soil amendments used in this study were four: (1) sintered fly-ash (a by-product of the hydroelectric power industry, fly-ash is heat-treated or sintered to produce a porous, inert, and rigid light-weight aggregate with about 70 percent pore space); (2) expanded slate (a commercially available material produced by a heat-expansion process so the slate, too, is porous (about 50 percent pore space), inert, and rigid); (3) coarse construction sand (not a light-weight aggregate, but an age-old and commercially available material); and (4) an organic material, digested sewage sludge.

After 4 years—even with continued visitor use—there are significant differences between treatments (table 3). The soil mix having 33 percent by volume of expanded slate has the lowest bulk density and the most pore space. The four treatments with sintered fly-ash fell between those with 33 percent and 20 percent of expanded slate. Coarse construction sand was not so effective an addition as either of the two aggregates, while the use of sewage sludge with the other materials had little or no effect. Effective soil amendments offer a partial solution for alleviating some of the deleterious effects of compaction. The best treatment gave an increase of 7 percent for pore space in the rooting zone, an increase that improves the air and water relationships for the growth of trees.

Infiltration and percolation data are not yet completed, but initial indications are that the modified plots handle more water per unit time than the controls. This is particularly important in reducing runoff and erosion during rain storms and in getting moisture into the soil so it is available for plant use. We have noticed that the plots exhibit a hydrophobic or

Table 3.—Bulk density and pore space of soils by treatments after 4 years with continued visitor use[1]

| Plot treatment | Bulk density | | Pore space | |
|---|---|---|---|---|
| | Average | Significance | Percentage[2] | Significance |
| | *g/cc* | | *Percent* | |
| 33% expanded slate | 1.33 | h | 49.8 | a |
| 33% expanded slate with sludge | 1.34 | h | 49.4 | ab |
| 33% sintered fly-ash | 1.41 | g | 46.8 | bc |
| 33% sintered fly-ash with sludge | 1.43 | fg | 46.2 | cd |
| 20% sintered fly-ash | 1.44 | ef | 45.9 | cde |
| 20% sintered fly-ash with sludge | 1.44 | ef | 45.9 | cde |
| 20% expanded slate with sludge | 1.45 | ef | 45.4 | cde |
| 20% expanded slate | 1.46 | de | 45.0 | cde |
| 33% coarse sand | 1.48 | cd | 44.3 | cdef |
| Rotary-tilled control | 1.50 | bc | 43.6 | defg |
| 33% coarse sand with sludge | 1.51 | b | 43.3 | defg |
| Undisturbed control | 1.52 | b | 42.9 | efg |
| 20% coarse sand with sludge | 1.55 | a | 41.5 | fg |
| 20% coarse sand | 1.56 | a | 41.2 | g |

[1] Data based on samples from three replications. Statistical analyses followed Duncan's multiple range test, and values with same letter in a column are not significantly different (at 5% level).

[2] In calculating pore space, 2.65 g/cc was used as the assumed particle density.

water-repellent tendency. This characteristic can apparently develop when soils become compacted. We hope further work will substantiate these indications and suggest possible amelioration measures.

Within the environment of the city and its parks, the general procedure has been to remove leaves and other naturally produced organic matter. This practice removes nutrients and organic matter from city soils *(Meyer 1973 and personal observations)*. However, organic materials as urban-soil amendments should be included in maintenance operations. Use of these materials is economically feasible, partly because of the number of brush and log chippers currently available and partly because of the high cost of purchasing adequate amounts of topsoil, fertilizer, and peat moss. The materials can be composted with sewage sludge (as the USDA has demonstrated at Beltsville) and provide a very desirable organic material for modifying urban soils. Such organic wastes do not, of course, totally replace topsoil and fertilizer in amending urban soils.

However, the value of these organic wastes is demonstrated by their use in Constitution Gardens, a 42-acre site between the Lincoln Memorial and Washington Monument *(Patterson 1975)*. Nineteen-hundred trees, numerous shrubs, and other vegetation are being used to create an informal park where Bicentennial visitors can relax. Typical urban soil existed at this site, so National Capital Parks had to choose between purchasing adequate topsoil to support the trees and other vegetation and building a soil—using the existing soil, 3 inches of USDA compost (digested sewage sludge and wood chips), 4 inches of leaf mold collected within the Washington area, and a small amount of topsoil. The existing soil, compost, and leaf mold were thoroughly mixed to form a soil mantle of 14 inches, over which a 3- to 4-inch layer of topsoil was placed. The results of soil data (table 4) indicate that

Table 4. Results of analyzing the soil mixture of Constitution Gardens[1]

| Date | pH | Organic matter | Soluble salts[2] | Magnesium[3] | Phosphate[3] | Potash[3] | Manganese | Zinc |
|---|---|---|---|---|---|---|---|---|
| | | *Percent* | *ppm* | *lbs/acre* | *lbs/acre* | *lbs/acre* | *lbs/acre* | *lbs/acre* |
| 11 Nov. 1974 | 6.7 | 4.6 | 2,100 | 300+ VH | 750+ VH | 450+ VH | 105 | 200+ |
| 22 Jan. 1975 | 6.2 | 4.6 | 660 | 300+ VH | 640+ VH | 297 VH | 50 | 183 |
| 1 April 1975 | 6.6 | 4.6 | 340 | 300+ VH | 750+ VH | 351 VH | 60 | 177 |

[1] Analyses made by the Soil Testing Laboratory of the University of Maryland.
[2] ppm = parts per million.
[3] VH = very high.

the fertility is mostly adequate to date. Nitrogen will have to be added because of the very low amount in the organic amendment. (Nitrogen analyses show 4 to 18 pounds of available N per acre.) We plan to continue such uses of organic materials in amending urban soils.

Still another soil-improvement project was in connection with a planting of elms that line the Reflecting Pool. The site received heavy use during Resurrection City and continues to receive heavy use annually during the National Folklife Festival. Soil beneath these trees was compacted, and the shading and compaction prevented adequate establishment of turf. Wood chips were applied broadcast during the summer of 1973 prior to the Folk Festival, and a year later observations were made. At the interface of wood chips and soil there was a dramatic proliferation of rootlets. Observations indicated that, as the wood chips decayed, the soil surface was beginning to reflect their influence. Additional wood chips can be applied as the old ones decay. Ultimately, this organic matter will improve water and aeration relationships through reducing compaction effects.

## CONCLUSIONS

Soil compaction imposes severe stress upon urban vegetation. Treatments tested by the Ecological Services Laboratory of the National Capital Parks have produced a significant reduction in soil compaction as measured by bulk density. Lightweight aggregates rotary-tilled into plots reduced soil compaction, even though the area was continually used as a playground-picnic area. Composts of leaves, wood chips, and sewage sludge help to reduce compaction of urban soils and also increase their fertility and content of organic matter. Wood chips, when used on heavily compacted soils in shaded areas, reduce damage to soil and to tree roots from continued heavy use. Such applications of organic materials aid the development of a "natural" soil profile.

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# SALTS AND WOODY-PLANT INTERACTIONS IN THE URBAN ENVIRONMENT

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*ABSTRACT.* The extensive use of de-icing salts in urban environments has resulted in significant plant pollution. Plants growing along highways, on lawns, and along sidewalks exhibit stem dieback, and many are killed. The salts are deposited as spray on buds, stems, and leaves or are accumulated in the root zone. Subsequent injury results from osmotic and specific ion effects. Several woody plants exhibit resistance to abnormal salt levels, and systematic breeding and selection for salt-tolerant plants are recommended.

TREES AND SHRUBS are often used indiscriminately for landscaping metropolitan areas where their adaptation to the habitat is questionable. Consideration is seldom given to the pollutants, soil conditions, and maintenance factors that determine the ultimate survival of the plant. Esthetic considerations — form, texture, foliage, flower, fruit, and fall color —often override the common-sense factor of whether the plant will survive. Man has created environments where a limited number of woody plants can be grown successfully. Unfortunately this complement of plants is primarily restricted to the weedy, less ornamental plant taxa.

We, as plant scientists, have not systematically selected plants for adaptation to specific habitats. Much of the selection accomplished to date has been by serendipity, and I strongly believe there is a pressing need for systematic and organized breeding and selection of pollution-tolerant trees and shrubs that have significant esthetic characteristics. Gold *(1975)* noted that plant species must be selected for tolerance to urban conditions; and the conditions he included were drought, poor aeration, compaction, mineral deficiencies, contamination by salts, heavy metals and pesticides, air pollution, and mechanical impacts by man. Epstein *(1972)* wrote that, like other stressful features of the mineral environment, salinity often results in the evolution of races, or ecotypes adapted to it. The possibility of breeding salt tolerance into plants exists, but the strategy has not been tried in any sustained energetic manner *(Demeritt 1970)*.

## THE NATURE AND SCOPE OF SALINITY:PLANT INTERACTIONS

The extensive use of de-icing salts in northern states has created a synthetic

saline environment unlike that encountered in the saline soils of the world. The increased interest in highway and municipal beautification, coupled with the increased use of de-icing salts, *(Westing 1969)* has produced an incongruous, but not unreconcilable, situation. Westing estimated that approximately 12 million tons of salt are applied to northeastern highways per year. Chicago freeways, in severe winters, have received as much as 80 tons per lane mile (45 metric tons per lane per km). On six-lane freeways the total reaches 480 tons per mile. The soluble salt content *(Hughes and others 1975)* of soils along the Chicago freeways varies considerably, and concentrations of 20,000 ppm (2 percent) were found on sparsely vegetated areas and up to 50,000 ppm (5 percent) in denuded soil from the medians. However, these high-salt soils represent only a small percentage of the total area, and the average soil would fall in the range of 500 to 2,000 ppm, which presents no problem to plant growth *(Richards 1954)*.

The metropolitan areas receive the greatest quantities of salts: in Illinois approximately 300,000 tons (272,000 metric tons) were applied to state-maintained roads during the winter of 1969-70, and Chicago expressways received 18 percent of this. Hutchinson *(1970)* indicated that average annual application of 15 to 25 tons per mile (8 to 14 metric tons per km) was common in several states, but also that rates within states varied widely.

De-icing salts present a significant cultural problem—one to which there are few logical alternatives. Plant injury occurs along freeways, along sidewalks, on lawns of suburban streets, and in other areas where salts are liberally used on the nearby roadways. The two principal de-icing salts are sodium chloride (NaCl), the primary source, and calcium chloride ($CaCl_2$).

Plants are injured by salts that are deposited by drift on dormant stems and buds of deciduous trees and on stems, buds, and leaves of evergreens, or by excess amounts of salts that leach into the root zone. Along Chicago freeways, plant injury was evident as far as 150 to 200 feet from the pavement's edge. Several authorities *(Hall and others 1972, Hofstra and Hall 1971, Lumis and others 1971, Lumis and others 1973)* agreed that the greatest percentage of injury to roadside plants resulted from aerial deposition, and not from soil-soluble salts, although injury has been attributed to salt accumulation in soils *(Davidson 1970, Hanes and others 1970, Holmes and Baker 1966)*. In suburban areas that are heavily de-iced and plowed, excess salts often accumulate in nearby lawns. Holmes *(1964)* reported that the superintendent of a New York City apartment house used copious amounts of NaCl for the sidewalks and could not understand why the trees were of reduced vigor and stunted appearance until someone broke a stem and was able to detect a heavy salt taste.

The resultant plant injury from soil salts may be caused by differences in osmotic potentials between the plant and the soil solution, by a specific ion effect usually related to the Na or Cl ions, or by a combination of the two *(Epstein 1972)*. Injury through osmotic effects results when the osmotic potential of the soil solution is significantly lower than that of the plant cells. Water does not move into the plant and could even move osmotically from the cells into the soil solution.

Another interesting explanation for osmotic injury *(Bingham and others 1968, Oertli 1968)* is that salt is absorbed by roots and moves into the outer spaces (vessels, cell wall areas) of leaf mesophyll cells. The osmotic potential of the extracellular solution may be low enough to cause an intracellular water deficit. This in turn could lead to the death of cells, especially those around the margins of leaves.

Plants injured through the osmotic mechanism are often stunted *(Dirr 1975)*; they may exhibit yellowing and eventual

abscission of lower leaves; development of leaf injury is usually acropetal. However, some plant taxa show no significant discoloration of leaves, but may have growth differences revealed by their fresh or dry weights compared to those of control plants. Separating osmotic from toxic effects of specific ions is almost impossible in the field because one may override or mask the effect of the other *(Dirr 1974)*. Although some plant injury is attributable to the osmotic effects of soil salts, the consensus of opinion is that plant cells are able to accumulate and maintain high intracellular concentrations of solutes—thereby keeping internal water potentials sufficiently lower than that of the external medium to effect an osmotic adjustment and prevent physiological drought *(Epstein 1972)*.

The mechanism of plant injury due to specific ions (Na or Cl) has not been established. Various salts or ions may disrupt the structure of enzymes or other macromolecules *(Rauser and Hanson 1966, Warren and Cheatum 1966)*, may damage cellular organelles *(Blumenthal-Goldschmidt and Poljakoff-Mayber 1968)*, may affect photosynthesis and respiration *(Boyer 1968, Nieman 1962)*, and may inhibit protein synthesis *(Kahane and Poljakoff-Mayber 1968)*. Disruption of any or all of these plant structures or processes could lead to death of cells, tissues, organs, and eventually the plant.

## SYMPTOMS OF AERIAL-SALT INJURY

Plant injury by salt is manifested in many different ways, but the consistency, intensity, and magnitude of injury can be accounted for only through the mode of aerial deposition. The following symptoms, as described by Lumis and others *(1971)*, accurately chronicle the visual evidence associated with salt injury. Evergreens often show:

1. Needle browning is moderate to extreme, beginning at the tip.
2. Needle browning and twig dieback occur on the side facing the road, but none or very little on the back side.
3. No needle browning or dieback occur on branches near the ground under continuous snow cover.
4. Needle browning and twig dieback are less severe farther from the road.
5. Browning usually is first evident in late February or early March and becomes more extensive through spring and summer.

Deciduous plants show:

1. Leaf buds on the terminal part of branches facing the road are very slow to open or do not open.
2. New growth arising from the basal section of branches facing the road results in a tufted or witches'-broom appearance.
3. Flower buds on the side facing the road do not open, but those on the back side develop variably.

General injury patterns include:

1. Injury is more severe on the side facing the road; plants are one-sided due to branch dieback.
2. Damage is more pronounced on the down-wind side of the highway.
3. Plants farther from the road are injured less.
4. Branches that were covered by snow are not injured.
5. Injury to evergreens becomes apparent in late winter; injury to deciduous plants is not evident until spring.
6. Branches above the spray-drift zone are not injured or are injured less.
7. Damage increases with the volume and speed of traffic and the amount of salt applied to highways.
8. Plants damaged over several years lack vigor and soon begin to die.
9. Less winter-hardy plants are injured more severely.
10. Salt spray penetrates only a short distance into dense plants.
11. Plants in sheltered locations lack injury symptoms.

## THE TOXIC PRINCIPALS

The Na and Cl ions are the two agents that must be considered in judging salt injury to woody plants. Sodium can replace essential cations (Ca, Mg, K) on the soil colloids and at the same time can deflocculate the soil. The reduction in flocculation (loss of granulation) affects drainage, soil-oxygen tensions, and, indirectly, microbial activities.

Most investigators *(Baker 1965, Dirr 1974 and 1975, Hofstra and Hall 1971, Holmes 1961, Holmes and Baker 1966, Shortle and Rich 1970, and Walton 1969)* attributed woody plant injury to the Cl ion, although Na has been implicated as a causal agent *(Bernstein and others 1972, Rich 1972)*. Chloride is a negatively charged ion and, unlike Na, is readily leached and therefore is briefly available in the root zone, especially in areas of high rainfall. C. R. Belcher *(personal communication 1975)* reported that 6 months after the application of 16,000 pounds per acre of rock salt, neither Na or Cl ions could be found in the top 12 inches of soil. Westing *(1969)* also reported that Cl is readily leached and is seldom available in significant concentrations in the soil for any length of time.

When Na and Cl ions are aerially deposited on plants, they usually penetrate the stems, buds, and leaves. Lumis and others *(1973)* noted that, although the basis for plant resistance to salt spray is not known, increased amounts of wax (bloom) on spruce needles added to their protection, because the bluer the spruce, the more resistant it was to salt spray. Deciduous trees and shrubs having resinous buds or buds partially embedded in the stem are resistant, while plants with naked buds (lacking scales) are susceptible to salt spray. Dirr *(1974)* speculated that the salt tolerance of thornless common honeylocust, *Gleditsia triacanthos inermis*, under highway conditions, was attributable to the inability of Na and Cl to penetrate the waxy branches and protected buds of dormant trees. However, honeylocust seedlings grown under controlled conditions where NaCl and KCl were soil-applied showed severe injury. Total soil-soluble salts were not responsible for injury, and tissue Na had no adverse effect on growth, although Na levels of shoots were greater than 2 percent of dry weight. Shoot content of Cl was a reliable index of the degree of salt injury, because the greater the tissue amount of Cl, the more rapid was the onset and the more severe the injury.

Dirr *(1975)* showed that *Hedera helix*, English ivy, was severely injured by soil and foliar applications of Cl-salts (NaCl, KCl, $CaCl_2$). The injury developed more rapidly, and initially was more severe, from foliar applications. However, the dry-weight reductions were similar among all Cl-treated plants at the end of the experimental period. Plants treated with foliar-applied $Na_2SO_4$ were vigorous, healthy, dark green, and similar to the controls, although Na levels of shoots were approximately 1 percent of dry weight. Levels of this magnitude produced visual injury in other woody ornamental species *(Bernstein and others 1972)*. The shoot-Cl levels that caused visual injury in honeylocust and English ivy were greater than 2 percent of dry weight regardless of the type of Cl salts or application methods.

My work to date has led me to believe that the degree of salt tolerance among woody plants depends on their ability to preclude Cl, and possibly Na, from entering cells and tissues. Work comparing *Pinus thunbergii* (Japanese black pine), a reported salt-tolerant species, to *Pinus strobus* (white pine), a salt-susceptible species, showed that both species were severely injured by daily foliar applications of Cl salts. Tissue analyses showed that needles of severely injured white pines had Cl contents greater than 3 percent, while injured needles of Japanese black pine contained approximately 2 percent. When Cl reaches a threshold level in plant tissue *(Dirr 1974)*, there are no cellular adjustments that offset toxic effects. Tissue levels of injured

plants are often extremely variable because of (1) "species specificity" (genetic differences among plants), (2) plant part sampled (leaves usually possess greater concentrations of ions than stems, and stems greater levels than roots), (3) time of sample collection [*Hall and others 1972* showed that foliar concentrations of Na and Cl declined from abnormally high levels, up to 1 percent in May to normal levels, 0.02 to 0.1 percent, by August in white pine], and (4) analytical techniques. LaCroix and others *(1970)* showed that different analytical techniques indicated different Cl levels in the same tissue.

The data in tables 1 and 2 show the great variation in shoot Na and Cl levels among various plant species. The visual injury and degree of salt tolerance observed on the plants listed in table 2 correlated very closely with shoot contents of Cl: *Hedera helix* was more salt tolerant than *Viburnum*>*Pyracantha*>*Coleus*>*Cercis*. Table 3 presents a compilation of leaf or shoot levels of Cl that produced plant injury. Shortle and Rich *(1970)* reported that foliar contents of Cl at the injury threshold were correlated with the degree of visual injury.

Salt tolerance of woody plants has too often been based on whether the plants had branch dieback or some other visual disorder. I have shown *(1975)* that the evaluation of a specific plant's adaptability to saline environments must be based on several parameters. Plant survival in saline soils does not automatically imply survival where salt is aerially applied and vice versa. *Thuja occidentalis* (eastern arborvitae) will withstand soil salts but not foliar-applied salts, while the opposite is true for honeylocust *(Dirr 1974)*. The appearance of the plant is not always indicative of the severity of salt-induced damage *(Lumis et al. 1973)*, and dry weights of shoots or other growth parameters should be used to augment visual evaluations. *Ailanthus altissima* (tree-of-heaven) seedlings were tested for tolerance to soil-applied Cl salts, and on the whole exhibited minimal resistance.

Table 1.—Sodium content of shoots of selected plant taxa as affected by salts and concentrations

[In percentage of oven-dry weight]

| Taxon | Control | $Na_2SO_4$ | | NaCl | |
|---|---|---|---|---|---|
| | | 0.05N | 0.15N | 0.05N | 0.15N |
| *Coleus blumei* | 0.21 | 3.70 | 4.53 | 3.62 | 4.93 |
| *Pyracantha coccinea 'Lalandi'* | .04 | .47 | .61 | .58 | 1.92 |
| *Cercis canadensis* | .03 | .36 | .86 | 1.18 | 7.06 |
| *Hedera helix* | .16 | .35 | .40 | .77 | .75 |
| *Viburnum x burkwoodii* | .03 | .23 | .52 | .46 | .98 |

Table 2.—Chloride content of shoots of selected plant taxa as affected by salts and concentrations

[In percentage of oven-dry weight]

| Taxon | Control | $Na_2SO_4$ | | NaCl | |
|---|---|---|---|---|---|
| | | 0.05N | 0.15N | 0.05N | 0.15N |
| *Coleus blumei* | 1.14 | 1.37 | 1.44 | 6.19 | 9.41 |
| *Pyracantha coccinea 'Lalandi'* | .31 | .31 | .24 | 1.71 | 3.67 |
| *Cercis canadensis* | .64 | .96 | 1.26 | 3.61 | 11.64 |
| *Hedera helix* | .38 | .34 | .41 | 1.39 | 1.94 |
| *Viburnum x burkwoodii* | .27 | .36 | .58 | .94 | 2.19 |

Table 3.—Chloride levels corresponding with plant injury as reported by various investigators

| Tree species | Chloride level in percentage of dry weight | | Investigator |
|---|---|---|---|
| | Damaged trees | Uninjured | |
| *Acer platanoides* | 0.4 or greater | — | *Walton 1969* |
| *Acer rubrum* | 1.01 | 0.3 | *Shortle & Rich 1970* |
| *Acer saccharum* | 1.0 (leaf necrosis) | .61 | *Baker 1965* |
| | 3.64 (stems dying) | — | *Holmes 1961* |
| | 1.0 (leaf necrosis) | .05-0.06 | *Holmes & Baker 1966* |
| | .84 | .24 | *Shortle & Rich 1970* |
| *Aesculus hippocastanum* | 1.0 or greater (leaf necrosis) | — | *Ruge 1968* |
| *Ailanthus altissima* | 2.0 to 3.0 | — | *Dirr, unpublished* |
| *Alnus rugosa* | .91 | .54 | *Shortle & Rich 1970* |
| *Carpinus caroliniana* | .94 | .34 | *Shortle & Rich 1970* |
| *Carya illinoensis* | 1.0 (leaf necrosis) | — | *Harper 1946* |
| | .6 or greater (trees were damaged) | — | *Harper 1946* |
| *Carya ovata* | 1.27 | .38 | *Shortle & Rich 1970* |
| *Gleditsia triacanthos inermis* | 2.56 (leaf necrosis, death of plant) | — | *Dirr 1974* |
| *Pinus mugo* | 1.12 (leaf necrosis) | — | *Hofstra & Hall 1971* |
| *Pinus nigra* | .78 (leaf necrosis) | — | *Hofstra & Hall 1971* |
| *Pinus resinosa* | 1.08 | .00 | *Shortle & Rich 1970* |
| *Pinus strobus* | 2.0 to 3.0 | | *Dirr, unpublished* |
| | 1.36 to 1.76 (leaves 70 to 90% necrotic) | | *Hall et al. 1972* |
| | .58 | .24 | *Shortle & Rich 1970* |
| *Pinus sylvestris* | .76 | — | *Hofstra & Hall 1971* |
| *Pinus thunbergii* | 1.5 to 2.5 (severe leaf necrosis) | — | *Dirr, unpublished* |
| *Thuja occidentalis* | .83 (leaf necrosis) | — | *Hofstra & Hall 1971* |
| *Tilia* species | 1.0 or greater (leaf necrosis) Levels up to 6.0 were found. | — | *Ruge 1968* |
| *Tilia americana* | .90 | .27 | *Shortle & Rich 1970* |
| *Tsuga canadensis* | .68 | .50 | *Shortle & Rich 1970* |
| *Ulmus americana* | 1.13 | .36 | *Shortle & Rich 1970* |

The seedlings did vary: 6 of 100 were uninjured while the others were defoliated during the 21-day experimental period. However, this species is sometimes listed as salt-tolerant (table 4). Near highways most of the salts reach *Ailanthus* stems aerially and apparently do not enter the dormant tissues of this species.

Evaluations of salt-induced plant injury should be based on salts, concentrations, application methods (aerial versus soil-applied), osmotic effects, shoot or leaf contents of Cl, and perhaps, shoot levels of Na. Elimination of any of these factors from consideration could result in misinterpretation of the salt resistance or susceptibility of a particular plant. The plants listed in table 4 have been reported to be salt-tolerant by various authorities; however, they have not been thoroughly tested and therefore cannot be recommended unequivocally.

There are several obvious inconsistencies in the list of salt-tolerant plants. These inconsistencies occur because evaluations are based on a single parameter and insufficient data.

## MINIMIZING SALT DAMAGE TO WOODY PLANTS

Salt damage to woody plants can be minimized or largely eliminated by:

1. Avoiding de-icing salts completely (often not feasible), reducing quantities applied, or using alternative deicing salts *(Krappenbauer et al. 1974, Westing (1969)* or alternative methods of snow and ice removal.

## Table 4.—Relative salt tolerance of trees

[By authors: (1) Carpenter 1970, (2) Dirr 1974 and 1975, (3) Lumis and others 1973, (4) Pellett, (5) Shortle and Rich 1970, and (6) Wyman 1965 and 1969.]

| Species | Salt-tolerance rating | | |
|---|---|---|---|
| | Good | Moderate | Poor |
| *Abies balsamea* | — | 1 | 4 |
| *Acer negundo* | — | 1,4 | 3 |
| *Acer platanoides* | 2,3,6 | 4 | — |
| *Acer pseudoplatanus* | 6 | — | 1 |
| *Acer rubrum* | — | 3 | 1,4,5 |
| *Acer saccharinum* | — | 3 | 4 |
| *Accer saccharum* | 3 | — | 1,4,5 |
| *Aesculus hippocastanum* | 3,6 | — | — |
| *Ailanthus altissima* | 3,6 | — | — |
| *Alnus glutinosa* | — | — | 1 |
| *Alnus incana* | — | — | 4 |
| *Alnus rugosa* | — | 3 | 1,5 |
| *Amelanchier canadensis* | 6 | — | — |
| *Amelanchier laevis* | — | — | 3 |
| *Betula allegheniensis* | 5 | — | — |
| *Betula lenta* | 5 | — | — |
| *Betula papyrifera* | 5 | 3,4 | — |
| *Betula pendula* | — | 4 | — |
| *Betula populifolia* | 5 | 3 | — |
| *Betula species* | — | 1 | — |
| *Carpinus betulus* | — | — | 1 |
| *Carpinus caroliniana* | — | — | 4,5 |
| *Carya ovata* | 3 | — | 5 |
| *Carya* species | — | — | 4 |
| *Catalpa speciosa* | — | 3 | — |
| *Celtis occidentalis* | 2 | — | — |
| *Corylus* species | — | — | 1 |
| *Crataegus crusgalli* | 6 | — | — |
| *Crataegus* species | — | — | 3 |
| *Elaeagnus angustifolia* | 2,3,4,6 | — | — |
| *Fagus grandifolia* | — | 1 | 3,4 |
| *Fagus sylvatica* | — | — | 1,4 |
| *Fraxinus americana* | 5 | 3,4 | — |
| *Fraxinus pennsylvanica* | — | 1,4 | — |
| *Gleditsia triacanthos inermis* | 1,2,3,4 | — | — |
| *Hippophae rhamnoides* | 6 | — | — |
| *Juglans nigra* | 3 | — | 1,4 |
| *Juglans regia* | 3 | — | 1,4 |
| *Juniperus virginiana* | 5,6 | 1,4 | — |
| *Ilex opaca* | 6 | — | — |
| *Larix laricina* | 3 | — | — |
| *Larix* species | — | — | 1,4 |
| *Magnolia grandiflora* | 6 | — | — |
| *Malus baccata* | — | 1,4 | — |
| *Malus* species and cultivars | — | 2,3 | — |
| *Morus alba* | 1,4,6 | — | 3 |
| *Nyssa sylvatica* | 6 | — | — |
| *Picea abies* | — | 3,4 | — |
| *Picea asperata* | 6 | — | — |
| *Picea glauca* | — | 1 | 3 |
| *Picea pungens* | 3 | — | — |
| *Picea pungens glauca* | 6 | 1 | — |
| *Pinus banksiana* | 3 | — | — |
| *Pinus mugo* | 3 | — | — |
| *Pinus nigra* | 3,6 | — | — |
| *Pinus ponderosa* | — | 1 | — |
| *Pinus resinosa* | — | — | 3,4,5 |
| *Pinus rigida* | 6 | — | — |
| *Pinus strobus* | — | — | 3,4,5 |
| *Pinus sylvestris* | 6 | 4 | 3 |
| *Pinus thunbergii* | 6 | — | — |
| *Populus alba* | 1,2,4,6 | — | — |
| *Populus alba* 'Pyramidalis' | 2 | — | — |
| *Populus angustifolia* | 1 | — | — |
| *Populus deltoides* | 3 | 1 | — |
| *Populus grandidentata* | 5 | 3 | — |
| *Populus nigra* 'Italica' | — | 3 | 1,4 |
| *Populus tremuloides* | 5 | 1,3 | — |
| *Populus* species | — | 3 | — |
| *Prunus armeniaca* | 1 | — | — |
| *Prunus serotina* | 5,6 | — | — |
| *Prunus virginiana* | 3 | — | — |
| *Pseudotsuga menziesii* | — | 1 | 4 |
| *Pyrus* species | — | 3 | — |
| *Quercus alba* | 1,2,4,5,6 | — | — |
| *Quercus macrocarpa* | 4 | — | 3 |
| *Quercus marilandica* | 6 | — | — |
| *Quercus robur* | 1 | — | — |
| *Quercus rubra* | 1,3,4,5 | — | — |
| *Rhamnus cathartica* | 2,3,6 | — | — |
| *Rhamnus frangula* | 2 | 3 | — |
| *Rhus typhina* | 2,3,6 | — | — |
| *Robinia pseudoacacia* | 2,3,4,5,6 | — | — |
| *Robinia pseudoacacia* 'Umbraculifera' | 2 | — | — |
| *Salix alba* | — | 1 | — |
| *Salix alba* 'Tristis' | 4 | — | — |
| *Salix matsudana* 'Tortuosa' | 2 | — | — |
| *Salix nigra* | — | 3 | — |
| *Salix* species | 4 | — | — |
| *Sorbus* species | — | 3 | — |
| *Syringa amurensis* japonica | 3 | — | — |
| *Tamarix pentandra* | 1,4,6 | — | — |
| *Taxus cuspidata* | — | 4 | — |
| *Thuja occidentalis* | — | 1 | — |
| *Tilia americana* | — | 3 | 4,5 |
| *Tilia cordata* | — | — | 1,4 |
| *Tsuga canadensis* | — | — | 3,4,5 |
| *Ulmus americana* | — | 3,4 | 5 |
| *Ulmus glabra* | 1 | — | — |
| *Ulmus pumila* | 4 | 3 | — |
| *Viburnum* species | — | — | 1 |

2. If soil is inundated with salty water, or plants receive aerial drift, a thorough leaching of the soil or washing of the plant parts will aid in reducing injury—if done soon enough. Obviously such ameliorative treatments are impossible in large-scale situations (highways, malls, planters) but could be used to advantage by some homeowners. Another recommendation is the addition of gypsum to soils that are high in Na. The calcium displaces the Na and improves soil structure and aeration.
3. Snow fences, including living fences of shrubs, and certain changes in highway engineering could significantly reduce the problem of salt drift and salty runoff and provide other advantages as well *(Westing 1969)*. Mounding of planting areas would prevent accumulations of excess salt in the root zone. Flemer *(1975)* advised that planting pits in sidewalks and blacktop areas should have a lip so the salty water does not run into the pits.
4. Plants that are injured and exhibit dieback should be pruned, fertilized, and watered. Weakened or stressed plants are often attacked by insects and diseases to which healthy trees are resistant.
5. Use plants sufficiently tolerant to the expected amounts and types of salt (soil salt or salt spray). As already mentioned, plants resistant to soil salts and those resistant to salt spray are not necessarily the same species. No plants are wholly immune to salt injury, although certain plant taxa endure more salt than others. A working list of woody plants, including those of good tolerance and moderate tolerance to the two types of salt, would significantly aid the landscape planner. Trees and shrubs with the highest degree of tolerance should be used in the most exposed areas, and those with moderate tolerance (and often increased ornamental characters) should be used in low-salt areas. The intolerant taxa would be restricted to areas where salts are not a problem.

The success or failure of our municipal landscaping programs depends on the use of trees and shrubs tolerant to salt and other pollutants. The mechanisms of plant resistance or susceptibility to salt are related to anatomical, morphological, and physiological considerations *(Bernstein and Hayward 1958, Epstein 1972, Hayward and Bernstein 1958, Sutcliffe 1962)*. A thorough understanding of the factors that govern plant tolerance to salt will permit systematic and organized breeding and selection. Any other approach to a research program will result in wasted time, effort, and money.

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# DISEASE STRESSES OF URBAN TREES

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*ABSTRACT.* The significant causes for disease stresses and decline of trees growing in an urban environment are reviewed. Both the effectiveness of various disease control procedures and the importance of proper tree selection in reducing future tree maintenance are discussed.

THE THREE NATURAL HAZARDS of field-crop production are weather, insects, and diseases. The same hazards are involved in growing and maintaining trees in urban environments. Although the same natural hazards occur in all plant cultivation, urban "tree farming" is complicated by the direct or indirect effects of man's concentrated habitation—his machinery, concrete, and soil disturbance. The fact that urban trees survive in seemingly impossible situations indicates their tenacity and ability to adapt to the many stresses that influence their growth and vigor.

Growing shade and ornamental trees in an urban situation involves planting conditions unfavorable for good growth. Even the native tree species may be regarded as exotic when planted along streets and around homes, because of the many unnatural environmental stresses placed on them. The effects of clay fill, soil compaction, rapid runoff of water, and the reflected heat from buildings and concrete are compounded by insect and disease problems.

This discussion is primarily concerned with significant noninfectious and infectious diseases that cause stress and decline of ornamental and shade trees grown in urban areas. Tree diseases, and all other stress factors, such as insects, mechanical injury, and unfavorable environmental factors, cause physiological stresses of various degrees. The arbitrary fragmentation of stress factors into pathological, entomological, and other types, is unfortunate, as the division gives the impression that these factors operate independently. The total effect of all stresses determines the vigor and ultimate survival of all plants. The evaluation of all potential stress factors must be considered in the selection of tree species for future planting.

## EVALUATION OF DISEASE DAMAGE

The International Society of Arboriculture *(1975)* recently published a guide for the professional evaluation of landscape trees, specimen shrubs, and ever-

greens. Most transplantable trees have a replacement value that can be easily established for a particular species and locality. However, because of esthetic qualities, medium- and large-size trees do not have readily ascertainable replacement values and are worth many times the value of similar timber trees growing in the forest. The value of such trees when used in noise abatement, atmospheric purification, screening, and control of solar radiation and wind is difficult to quantify. It is impossible to assess accurately the loss to a community from a devastating disease such as Dutch elm disease. Published figures on losses due to Dutch elm disease have been educated guesses rather than appraisals based on accurate data.

## NONINFECTIOUS DISEASES

### Environmental Stresses

The importance of several environmental stress factors to predispose plants to disease susceptibility was reviewed by Schoeneweiss *(1975)*. Of all the stresses related to climate, prolonged dry periods and soil-water deficiencies have the greatest effect on the amount of growth a tree produces each year. The cambium growth either slows down or completely stops, depending upon the amount of available soil moisture. Drought will not only affect growth during the current growing season, but can affect growth in later years. A summer drought affects the number of leaf initials formed in new buds, which produce shoot growth in the following year. A reduction in both the number and size of leaves directly affects the amount of carbohydrates and hormones produced the following year *(Kozlowski and Davies 1975)*.

Although there have been periods when only portions of the United States have been affected by drought, there have been years or series of years when drought has been general over the entire continent. Serious droughts occurred in 1749, 1762, 1860, 1925, the 1930s, and 1957 *(Parker 1965)*. General droughts throughout the country are perhaps not as important as sporadic and scattered localized droughts that occur annually.

Frequently, tree declines are associated with excessive soil moisture, due to excessive rainfall, and with prolonged drought periods. Decline and permanent damage to the root system usually results. Some of the major diebacks and declines resulting from too much or too little moisture are birch, sweetgum, maple, and ash dieback; and oak and sycamore decline. A brief description of these follows. For additional information on tree decline, the reader is referred to a paper by Sinclair *(1966)*.

### Birch Dieback in Canada

The yellow and paper birch species are affected primarily by diebacks. The symptoms are thinning of the crown and chlorotic and curled leaves. Low precipitation, early March thaw, and high soil temperature have been considered as possible causes for decline *(Braathe 1957, Hawboldt 1947, Redmond 1957)*. Berbee *(1957)* and Clark and Barter *(1958)* believe the disease may be caused by a virus.

### Sweetgum Blight in the South

Sweetgum blight appears as a thinning of the crown due to the reduction in the number of active buds and as dwarfed and chlorotic leaves. Prolonged drought periods seem to coincide with periods when disease development is most severe *(Toole and Broadfoot 1959)*.

### Maple Blight in the East and North

Maple blight was described by Welch *(1963)* and Hibbin *(1962)* in New York and by Houston *(1962)* in Wisconsin. The first symptoms are the death of terminal buds and dieback of branches. The disease appeared to be associated with insect defoliation in 1956 and 1957 in conjunction with dry summer periods. General recovery occurred in following years.

### Ash Dieback in the East

Ash dieback appears as a dieback of twigs, followed by dwarfed and chlorotic foliage and extensive dieback of larger branches. Cankers commonly develop on weakened branches. It is concluded that dieback is induced by periods of low rainfall, with fungi acting as secondary invaders and accelerating the death of affected trees through severe stem and branch cankering *(Ross 1966)*.

### Oak Decline in the East and North

Oak decline was first reported to affect scarlet, red, and black oaks in Pennsylvania and West Virginia. The symptoms appear as a general decline and dieback with stunted and chlorotic foliage. Generally, it is believed that this disease is the result of a severe and prolonged drought, associated in most cases with insect defoliation, canker-producing fungi, and bark beetles *(Goddard 1955, Fergus and Ibberson 1956, Gillespie 1956, True and Tryon 1956, Tryon and True 1958)*.

In 1972, there were reports of oak decline occurring in northern Illinois, primarily in the Chicago area. Those species most affected were white, swamp white, bur, red, and black oaks. Along the lake shore north of Chicago, oak decline is believed to be caused by several years of partial to complete spring defoliation by the fall cankerworm. Oak decline was also attributed to excessive rainfall. In widely scattered areas around Chicago and northern Illinois, excessive spring rains for three consecutive years are believed to have damaged the roots of red and white oaks. The weakened trees were then heavily attacked by various species of bark borers (author's unreported observations).

### Sycamore Decline

Sycamore decline was first observed in 1961 in the East St. Louis area. The symptoms are a general scorching of leaves followed by extensive dieback over a period of 2 to 4 years. The disease is believed to be caused by the combined effects of several stress factors. Drought, sycamore anthracnose, and air pollution are most likely involved. Canker-producing organisms extensively attack trees under stress and kill the affected trees *(Ricketts 1975)*.

## OTHER COMMON STRESS FACTORS

### Low-Temperature Injury

Plant tissues may be injured when temperatures drop near or below freezing (32°F). Freezing conditions following a gradual drop in temperature are seldom harmful to most trees after they have started to go dormant in the fall. However, a rapid drop in temperature following a period of mild weather can cause extensive damage. Trees exposed to winds or direct sunlight are more likely to be injured than those in sheltered locations. Low-temperature injury usually occurs on species planted outside their natural range, especially those moved from a mild climate to a severe climate.

A sudden drop in temperature following a warm autumn may cause the death of plant tissues that are not mature enough to withstand freezing conditions. The injured tissue is often confined to succulent shoot growth that is still internally active beyond the point of normal growth cessation. Terminal dieback will become evident the following spring.

Low-temperature injury during the winter dormant season affects the roots, trunk bark, twigs, and vegetative and flower buds. This injury occurs following abnormal warm periods during the winter months. Poor drainage, the genetic character of the root system, lack of snow cover, and soil type are other factors that contribute to root injury during the dormant period.

Frost cracks on trees are caused by the expansion and shrinkage of bark and wood, which cause internal mechanical stress and result in the cracking or splitting of the wood and slipping of bark at the cambium layer. Tree species

commonly affected by frost cracks are London plane, oak, elm, maple, horsechestnut, linden, tuliptree (yellow-poplar), and willow. Frost cracks on London plane trees often reopen when the air temperature falls to 8°F and remain open until temperatures warm in late winter. Usually these cracks never close completely, making entrance easy for insects and wood-rotting fungi and eventually causing deterioration of the heartwood.

Frost-heaving many times affects newly planted trees. Ice formation in the friable soil around and under new trees often displaces or heaves the tree and causes root damage. Displaced trees lean, and the displaced root systems do not settle to their original levels.

### Soil Nutrient Deficiencies and Soil Pollution

Of the 16 nutrient elements commonly required for normal tree growth, 9 are required in substantial amounts and 7 are required in relatively small amounts. Abnormal metabolism may result if one or more of the essential elements are lacking, or if they are in abnormally high concentrations in the soil.

Tree nutrition is often emphasized as very important in nursery production, but less emphasis is given after transplanting. Proper nutrition is essential for normal growth and development throughout the entire life of any tree. Tree nurseries are usually located where soils are optimum for rapid tree growth. If nutrient problems occur in the nursery, they are rather easily corrected. However, in larger urban trees, nutrient problems often occur that are both difficult to diagnose and expensive to correct. Deficiencies can often be diagnosed by analyzing plant tissue and soil samples. These methods do have limitations in making accurate diagnoses, since drought, extreme wet weather, leaching, soil type, and pH may affect the validity of the tests.

Factors that regulate the amount of nutrients absorbed by tree roots are concentration of the nutrients, topsoil depth, texture and structure of the soil, type of subsoil, soil pH, and soil compaction. The greater the depth of the topsoil, the greater volume of soil with physical, chemical, and biological characteristics favorable for root growth. Soil texture and structure affect the water-holding capacity, aeration, and nutrient content. Heavy clay soils afford poor water drainage, aeration, and nutrient availability.

The subsoil is important because of its effect on the drainage of gravitational water from the topsoil. A tight heavy subsoil will cause frequent waterlogging of the topsoil during rainy periods. Soil compaction affects both aeration and water infiltration into, and percolation through, the topsoil. Root penetration and development are poor in heavy, compacted, poorly drained soils.

Soils in urban areas, particularly along streets and around homes, are often excellent examples of poor soil conservation and management. The refuse left from basements, foundations, storm sewers, and water- and gas-line excavations is usually spread over the surface. This type of deep subsoil is often heavy clay, variable in nutrients, and low or lacking in organic matter. It usually contains limited amounts of both nitrogen and potassium and can be deficient in several of the other essential elements.

The general symptoms on trees affected by nutrient deficiencies have been discussed by Smith *(1970)*. The nutrient most often lacking in plant growth is nitrogen. There is considerable evidence that under natural conditions most of the nitrogen in the soil accumulates in organic forms from the biological fixation of atmospheric nitrogen. The bulk of the nitrogen absorbed from the soil by plants is stored in decomposed plant material. Microorganisms in the soil must break down plant material into simple inorganic components before the nutrients are reused by trees. When nitrogen is lacking, it causes pale green foliage, stunted top growth, and yellowing or drying of the

older leaves, especially during droughts. Good fall color on maple, oak, and many other tree species is often an indication of nitrogen deficiency and general poor vigor. Maples and oaks that have been fertilized in the spring, and given supplemental watering during dry periods, usually remain green longer in the fall and do not develop good fall coloration.

Chlorosis occurs on several tree species due to the lack of iron, manganese, magnesium, boron, and zinc. The most common deficiency of pin oak, sweetgum, maple, baldcypress, hackberry, white oak, and several other deciduous or evergreen species is the lack of iron or manganese.

Symptoms of iron chlorosis develop on pin oak when the soil pH is 6.7 to slightly more than 7.0. Many pin oaks appear normal for years when not disturbed by construction or other soil disturbance. Lawn fertilization and watering with city water often change the soil pH after a few years. Many fertilizers contain large amounts of calcium carbonate. Although this chemical does move slowly through the soil, frequent applications of calcium carbonate over the years will change the soil pH.

Some pin oaks growing in nursery rows and along streets remain a normal green color while many others become chlorotic. This variation among pin oaks suggests that some genetic difference may occur and that it may be possible to select cultivars tolerant of high pH. Procedures for correcting iron chlorosis have been reported *(Schoeneweiss 1973, Neely 1973, Neely and Schoeneweiss 1974)*.

### Stress Caused by Air and Soil Pollution

Nelson *(1967)* estimated that more than 50 percent of the American population live in areas of constant air pollution. All urban trees are living in constant soil or air pollution of one type or another.

Gaseous air pollutants, such as $SO_2$, halogen compounds, ozone, ethylene gas, and nitrogen oxides cause visible foliage injury to different tree species *(Brandt and Heck 1967, Sinclair and Costonis 1968, Heggestad 1968, U.S. Forest Service 1973)*. Under urban conditions, relatively few investigations have been made on the effects of long-term chronic exposure to low levels of pollutants of the air and soil. Long exposure to various pollutants can cause stresses that reduce growth and vigor.

Natural pollutants such as hydrocarbons from the conifers, methane gas from the marshes, hydrogen sulfide from decaying vegetation, air-borne soil particles, pollen, fungus spores, volcanic dust, and radiation have been in existence during the evolution of trees. For thousands of years, tree species have been naturally selected for surviving the environmental stresses caused by these pollutants.

Published reports indicate that 2,4-D and 2,4,5-T may cause extensive injury to foliage due to aerial drift of the spray and to volatile materials that evolve after application *(Goodwin and Niering 1962, Niering 1959, Phipps 1963)*. Much of the injury was believed to result from improper application and former use of highly volatile forms of the herbicides.

Neely and Crowley *(1974)* reported that, of 11 herbicides commonly used to control weeds in lawns, only dicamba consistently caused phytotoxic symptoms when applied to the soil. No phytotoxicity was observed with the use of bandane, benefin, bensulide, 2,4-D, DCPA, DSMA, siduron, silvex, 2,4,5-T, and trifluralin when applied at three times the recommended rate.

Visible chemical injury on nontarget plants is evident each year, and in 1975 over 10 percent of the tree and shrub specimens sent to the diagnostic laboratory of the Illinois Natural History Survey showed definite symptoms of chemical injury. A high percentage of the chemical injury resulted from the use of weed killers such as 2,4-D in lawn fertilizers and from surface spray applications. Much of the damage is apparently caused by applications that create fine particles easily carried by air movement to nontarget plants.

## INFECTIOUS DISEASES

Many good books and circulars review ornamental- and shade-tree diseases for various parts of the country. Many of these publications cover both insect and disease problems. The bibliography lists a few useful as general references *(Carter 1972, Shurtleff 1962, Smith 1970, Wallner 1975, Hepting 1971, Pirone 1970 and 1973)*.

The infectious diseases are often more dramatic and cause specific symptoms that are more easily differentiated from one another than those caused by noninfectious agents. Infectious diseases are caused by fungi, bacteria, viruses, and mycoplasma. More is known about diseases caused by fungi and bacteria than about those caused by viruses and mycoplasma. This does not mean that the latter two agents are less important, but that they are highly specialized fields in which relatively few researchers have worked on specific tree problems.

Many of the important urban tree diseases caused by fungi and bacteria are not serious in forests and wooded areas, and economically important diseases of forests are often not serious in urban areas. White pine blister rust, chestnut blight, and oak wilt are considered serious diseases of the forest in areas where the affected species are the predominant species of the forest. Because of the lack of hosts or of efficient insect vectors, these diseases are usually of little concern in most urban areas.

### Vascular Wilt Diseases

Oak wilt has caused loss of some oak trees in suburban areas of the Midwest where new homes have been constructed in stands of native oak. The recreational value of some parks and forest preserves has been lost due to the loss of oaks. Oak wilt is known to affect all species of oaks, but it is most serious among species of the red oak group. Oaks in urban areas do not appear to be threatened by this disease.

Many trees and shrubs are affected by Verticillium wilt, a vascular fungus disease. It is the only vascular disease that affects such a wide variety of unrelated annual and perennial plants. The disease is rare in forest stands, but is becoming increasingly prevalent in ornamental plantings, especially in temperate regions of the world. Presently, 60 tree and shrub species and varieties are known to be susceptible *(Himelick 1969)*. Since there is evidence that the fungus isolates differ in virulence to various hosts, the transporting of infected ornamental plants from one area to another may account for the appearance of the disease in areas where it has not been previously observed. It is likely that the indiscriminant movement of nursery stock from one region to another will eventually cause complete distribution of the more virulent strains to areas where they did not exist before. There appear to be differences in susceptibility within some tree species propagated from seeds—e.g., maple, redbud, and ash. However, the planting of a vegetatively propagated susceptible clone or variety could prove to be a serious problem in areas where the more virulent strains of the fungus occur.

Verticillium wilt symptoms can be difficult to diagnose on some of the less susceptible tree species. Trees weakened by the disease, because of the death of portions of the root system, may be more susceptible to the effects of other stress factors.

### Leaf Diseases

Spray control is usually recommended for most leaf diseases to prevent loss in foliage and ornamental appearance. Loss of ornamental effect is often temporary, but loss of foliage, if severe, may have a long-term effect. Synthesis, movement, and storage of food reserves is lowered even in vigorously growing trees *(Parker 1970, Smith 1970)*. Older and less vigorous, slower-growing trees are more seriously affected, since the decrease in growth is often greater the following year. Awareness of the disease susceptibility of

various tree species to leaf diseases will permit proper timing of effective fungicide sprays. Improper timing of spray applications may make them worthless and expensive in time and money. Few leaf and canker diseases, except powdery mildew and scab, can be eradicated by fungicide spraying. Several leaf diseases are erratic in their severity and usually are important if heavy defoliation occurs early in the growing season for two or three consecutive years. Often it is more practical to apply water during drought periods than to spray. Unless trees are low in vigor, they will usually respond well to applications of fertilizer in the spring and supplemental watering during dry periods of the summer.

## CONTROL OF INFECTIOUS TREE DISEASES

There are at least four major concepts of control for infectious tree diseases: exclusion, eradication, protection, and resistance. Each of these control procedures is important in limiting tree loss from infectious diseases.

### Exclusion

Exclusion refers to control procedures that prevent the movement of plant pathogens or disease agents into areas where they are not known to exist. Seeds and vegetative parts used for reproductive purposes are often treated to prevent the introduction of undesirable organisms into new areas. When symptoms or other signs of infectious organisms are present, the infected plant material can be culled. Disease agents, such as viruses in the seed or other plant material, are easily transmitted in plant material used for propagation and, therefore, are difficult to control. Nursery inspections for certification and state quarantines have been effective in limiting the movement of certain insects and diseases to new areas of the country. United States quarantines are adopted to control the importing and exporting of plant materials, and these materials are subject to inspection and in some cases fumigation before they are shipped.

### Eradication

Activities associated with removing or destroying all or parts of an infected tree constitute control by eradication. Destruction of diseased trees, removal of alternate hosts, and chemical therapy are procedures that may be used to control some of the infectious diseases we have in urban situations. Eradication of a canker disease on an individual infected tree is often the primary means of control; however, it may fail if the infectious organism has progressed into the trunk or if the tree is weakened and subject to multiple infections throughout the branches and twigs. Control of Dutch elm disease by eradication of diseased elm trees has contributed to the significant decrease in annual loss in most communities that also spray to control the insect vector. Control of chestnut blight by eradication has not been effective, and all such efforts to lessen tree losses have failed.

Removal of alternate hosts to rusts has not proved practical in urban situations simply because no one wants to destroy an ornamental plant until it is practically dead. If, however, more thought were given to planting, crabapples and hawthorns would be located at greater distances from susceptible junipers, and a reduction in the amount of infection on all hosts would be realized. The judicial use of rust-resistant varieties of crabapples and junipers would help to eliminate the problem.

Chemotherapy is a control method that may be used as an eradicant or a protectant. Various procedures have been used in testing chemicals that inhibit development of a pathogenic agent within a tree. Those procedures that have shown the greatest promise for internal therapy involve either soil injection or direct injection of chemicals into the vascular system. Although entomologists have recommended several systemic chemicals to

control insect pests, plant pathologists have only a few compounds that may be effective chemotherapeutants. There have been many disappointments in the research work with chemotherapeutants, particularly in the systemic control of vascular diseases such as Dutch elm disease, oak wilt, and Verticillium wilt. Research plant pathologists currently working on chemotherapy are still optimistic that compounds such as the solubilized forms of benomyl and TBZ (thiabendazole) may prove to be effective chemotherapeutants, particularly for Dutch elm disease control.

### Protection

Fungicide and bactericide sprays often must be used to prevent ornamental loss of leaves and fruit. Complete control of a leaf disease by protective fungicides is seldom achieved, especially during those years when disease incidence is severe. Improper timing of spray application, use of the wrong fungicide, and excessive rain often result in failure to control many tree diseases effectively. Even with the limitations of time and knowledge, spray control should be used if the climatic conditions may be optimum for severe infection and heavy defoliation early in the growing season. I discourage the use of more than two applications of a protective spray, because the limited amount of added protection usually does not justify the added cost of labor and chemical.

### Disease Resistance in Plants

Disease-resistant trees can be obtained in several ways. The most common methods used to produce resistant varieties are selection, hybridization, and induced mutations.

#### *A. Selection for disease resistance*

Trees resistant to pathogens and pests are likely to be found in regions where the plants originated or subsequently have been grown for a number of years. In such locations, a long association between pathogens and the tree species has occurred, with the consequent elimination of susceptible plant genotypes through natural selection. The relocation of naturally selected disease-resistant trees in other areas may prove that resistance no longer exists because of the presence of different races of the pathogen or different environmental conditions. The tolerance of certain tree species to disease may arise from imperfect synchronization of the pathogen and tree, as in diseases which occur in mature trees. Vigorous young trees may be able to replace diseased leaves or roots and so produce enough food reserves in spite of annually occurring infections. Some leaf diseases may fall into this category; precise knowledge of the injury they cause is lacking, and the injury may be more serious than is generally thought.

A limited list of tree varieties showing resistance to a few diseases was compiled by Stevenson and Jones *(1953)*. Although such a list may be of limited value in ornamental and shade tree breeding, other reports include additional tree species resistant or susceptible to tree diseases *(Gerhold and others 1966, Himelick, 1968, Himelick and Neely 1960, Neely and Himelick 1963, Nichols and Brewer 1973, Smith 1973)*.

#### *B. Hybridization*

The progeny from field-grown, disease-resistant plants may show a wide range of resistance and also be unduly susceptible to other pathogens or pests. In such cases a long-term program of plant breeding may be necessary to obtain satisfactory resistant varieties. As Smith *(1970)* pointed out, resistance mechanisms in plants are extremely diverse, and the problems associated with incorporating resistance in plants are complicated by the possibility that the fungus or bacterium can change genetically to circumvent the plant's defense.

Because adequate resistance cannot always be found in natural selections, other sources of resistance have to be used. This problem involves crossing the resis-

tant but perhaps otherwise undesirable trees with susceptible but commercially acceptable varieties in an effort to combine resistance and beauty. This combination has been sought in breeding for resistance to the Dutch elm disease. Crosses have been attempted between the susceptible American elm and certain native, Asiatic, and European elm species that are resistant to the disease *(Smalley and Kais 1966)*.

### *C. Induced mutations*

Inducing mutations is a long-term approach to the problem of finding suitable resistance in tree selections that otherwise have desirable cultural characteristics. Irradiation and chemical mutations have been developed by treating tree seeds and young seedlings. The chances of obtaining resistant mutants would appear very slight unless large numbers of tree selections were tested and a very complicated screening program were designed to obtain the best selections.

A prominent plant pathologist, Dr. J. C. Walker, reviewed the problems and progress in controlling plant diseases by host resistance and the practical application of resistance to problems in horticulture and agriculture. In his summary Walker wrote, "By and large the development of resistant varieties must be looked upon as a continuing program. The potential variability of most pathogens (including viruses) will not permit any currently successful [plant] variety to remain resistant, for an indefinite period" *(Walker 1959)*. Generally his summary reflects the opinion of plant pathologists and breeders alike. This opinion is based on a long history of setbacks in the breeding of resistant varieties. Frequently new varieties have appeared with resistance that at first seemed adequate but later proved not to be long lasting. The resistance was matched with new or previously rare races of the pathogen and was lost. The development of new plant varieties is a continuing program.

In tree breeding and selection we have often stressed the tree species or variety as the principal factor concerned in disease resistance. In actuality three factors are involved and are referred to by Van der Plank *(1968)* as "the disease triangle. A more susceptible host, a more aggressive pathogen, and an environment more favorable to disease all increase disease. It is convenient to call host-pathogen-environment interactions the disease triangle." All three factors affect the rate of infection. The rate of infection summarizes the effects of the genetic resistance of the host, its age and size . . . , the abundance of pathogen inoculum, its virulence and aggressiveness . . . , and the environmental effects; e.g. the rainfall, relative humidity, air temperature, and all other relevant factors.

Before being released for large-scale propagation and planting, new disease-resistant varieties must be adequately tested as to disease resistance and all other desirable or undesirable characteristics. The tests should be carried out over several years and over the range of climatic and urban environmental conditions which the trees are likely to encounter. Their susceptibility to other pathogens and pests, their rate of growth, and their aesthetic qualities should be accurately assessed and recorded. The breeding and testing of resistant varieties of trees should be carried out on a worldwide basis so that maximum advantage can be taken of resistant varieties in as large an area as possible. With increasing understanding of the genetical basis of resistance to pathogens in trees and of virulence in pathogens, disease control by the propagation of resistant tree varieties will become more widespread in the ornamental- and shade-tree industry.

## TREE SELECTION AND FUTURE MAINTENANCE

Urban tree selection has changed considerably during the past 30 to 50 years. Elm, pin oak, London plane, American sycamore, and Norway maple were for-

merly the most common species selected. All were relatively easy to transplant and grow and, therefore, represent the most common tree species lining our streets in many parts of the country. Each of these species has serious disease problems that now require high maintenance costs. To reduce these costs, a more scientific selection of tree species is needed.

Arborists, landscapers, and nurserymen realize the importance of proper tree selection in reducing future maintenance costs. Unfortunately, human emotions rather than basic tree information often influence the choices of many city officials as well as homeowners. The rapid loss of elms from Dutch elm disease caused tremendous expenditures to remove dead trees and replant denuded streets—expenditures that strained many municipal budgets. This was especially true in most cities and towns of the Midwest with populations of less than 100,000. Many midwestern cities lost 500 to 2,000 elms a year during the peak spread of Dutch elm disease in the early 1950's to late 1960's. It was not unusual for a moderate-sized city to spend over $100,000 a year removing trees and spraying for control of the elm bark beetle.

Very few of the smaller communities have a tree ordinance to control shade-tree replacement. In many midwestern communities, homeowners have replanted street trees and maintained them at their own expense. Unfortunately, tree selection was left to the discretion of the homeowner.

As an example, in 1950 approximately 52 percent of the total tree population in Urbana, Illinois, were elms *(Carter and Carter 1974)*. Only 15 of the original 4,235 elms are still alive. Many of the trees planted to replace the elms were planted by the homeowners. A 1975 survey of Urbana street trees showed that 80 percent of the tree population (7,322) are composed of 13 species. Five of these 13 species (37 percent) are now serious maintenance problems for the city. Two devastating ice storms in the past 15 years have damaged many silver maples and Siberian elms. The problems of the mimosa webworm and a leafhopper on honeylocust, iron chlorosis of pin oak, and sycamore anthracnose have made those species liabilities to the community.

Midwestern city arborists and homeowners are perplexed by the problems of selecting maintenance-free tree species. There are, in fact, no maintenance-free tree species; but some require less maintenance than others. Many tree species are relatively free of infectious-disease problems but are affected by insect and noninfectious-physiological-disease problems.

At least 10 species have been recommended in Illinois for replacing elms lost to Dutch elm disease. It was further recommended that municipalities avoid planting high percentages of only one or two species to avoid large losses if and when a serious disease or insect epidemic occurs. Experience over the past 25 years has proved that 10 tree species are not enough.

Nurseries are not always able to meet the demand for large numbers of one particular species of the size requested, and inflation has raised the cost of the more desirable species. Although supply and purchase cost are important factors in selecting suitable tree species, the real problem comes in maintaining inferior tree species during their useful life span under average urban environmental conditions.

Of the more than 300 tree species that will grow in most of Illinois, many are useful for ornamental purposes. Approximately 15 species have been widely planted. Table 1 lists species most frequently planted during the past 25 years and the disease and insect problems most commonly associated with them. With the exception of the crabapples and hawthorns, these species should be placed on a restricted list and used only in special cases where no other species can be substituted. Crabapples and hawthorns that are resistant or moderately susceptible to

**Table 1.—Disease and insect problems of tree species most frequently planted in the Midwest**

| Tree species | Problems |
|---|---|
| Siberian and American elms | Elm leaf beetle, Dutch elm disease, wetwood, and ice-storm damage; phloem necrosis of American elm |
| Silver maple | Ice-storm damage |
| Honeylocust | Leafhopper damage, mimosa webworm, and Kaskaskia canker |
| Pin oak | Chlorosis |
| American sycamore | Anthracnose, leaf-feeding insects, and decline |
| White birch | Bronze birch borer |
| Crab (many species and cultivars) and hawthorn | Scab, rust, fire blight, and powdery mildew |
| London plane | Canker stain, leaf-feeding insects, frost cracks, and decline |

the four diseases listed should be used *(Nichols and Brewer 1973, Smith 1973)*.

If a vascular disease, such as Verticillium wilt, were to become a serious problem in any one area of the country, it could not be eliminated by any known control measure. We will aparently have to live with the problem and hope that future resistant varieties are developed. Randomized planting of susceptible species and limiting each susceptible species to less than 5 percent of the total tree population should provide the most effective means of limiting future tree loss.

## CONCLUSION

Stresses placed on urban trees by man equal all natural stresses. Many of the tree problems caused by infectious and noninfectious diseases can be substantially decreased by proper tree selection, planting, and maintenance. The public's desire for quick shade has resulted in the planting of many tree species that require considerable maintenance. We are constantly encountering new disease and insect problems. Many of these problems appear to be developing due to the planting of new tree selections and cultivars in areas where they have not been grown before under urban conditions. Relocating susceptible tree species in areas where infectious organisms exist permits a pathogenic relationship to develop. A natural selection will occur as the resistant trees will survive and the more susceptible trees will die, but this is a very expensive route to travel.

Disease control through development of resistant varieties is an area that needs concentrated and extensive research. The selection, propagation, and breeding of naturally disease-resistant varieties is the most efficient and inexpensive means of disease control. The millions of mature trees growing in our continental urban areas could be evaluated by well planned and coordinated efforts of scientists and other professionals.

The first line of defense against diseases and insect pests starts with the propagation, selection, and planting of tree species and cultivars that do not have chronic problems. Some tree-evaluation studies are presently under way, which will give valuable information on growth characteristics *(Chapin and Kozel 1975)*. Tree selection and evaluation studies should be initiated on a national basis. All aspects of selecting tree cultivars and varieties should be adequately considered and evaluated. Form, rate of growth, and ultimate size are important in proper landscaping. Future studies should include all disciplines involving trees—the professional fields of nursery management, horticulture, genetics, entomology, landscaping, and plant pathology. We must carefully evaluate all factors involved in the planting and maintenance of trees in the urban environment.

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# IS HOST RESISTANCE A PRACTICAL GOAL FOR CONTROL OF SHADE-TREE INSECTS?

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*ABSTRACT.* Breeding for trees resistant to insects is an intriguing but difficult possibility. Some research is necessary in even determining that certain trees possess resistance to specific insects, not some form of pseudoresistance. In view of the pressure for research on other phases of breeding better shade trees, the search for and development of insect resistance will be of low priority. The use of insecticides will continue in the foreseeable future to have the primary role in controlling insect pests on shade trees.

THE IDEA OF UTILIZING natural resistance to insects as one method of developing better trees for metropolitan landscapes is intriguing and promising. The concept is biologically sound, environmentally constructive, and in practice would involve no outlay of operating funds or manpower. It would be an ideal ultimate solution to insect pest problems. But is this method attainable or feasible? If so, how and to what extent can it be achieved with shade or ornamental trees? If not, why not?; and how can valuable tree resources be protected and preserved?

The purpose of this discussion is to evaluate the concept of insect resistance in shade trees in an attempt to answer these questions. It will be of necessity a subjective analysis, since there is a paucity of literature on shade tree resistance to insects. Resistance in agricultural crop plants has been investigated for half a century with some successes. In forestry, research on resistance is more recent and less extensive. The most comprehensive review of the subject is the proceedings of a 1964 symposium on Breeding Pest Resistant Trees *(Gerhold and others 1966)*, including a thorough literature review of resistance to insects in forest trees *(Gerhold 1966)* and an analysis of the present status and future potential of insect resistance in forestry *(Callaham 1966)*.

Although 11 years have elapsed since that symposium, and more people are exploring insect resistance in forest trees, the subject is still in the pioneering stage. Virtually no research has been done with insect resistance in shade trees. In general, there is an urgent need for much more extensive research on shade-tree entomology and the development of a better strategy for protecting ornamental trees from insects. Pursuing the goal of

insect resistance will require long, extensive, and costly experiments.

Insect depredation is a major stress factor for shade trees, not only as a direct threat to health, vigor, and survival, but also when it predisposes trees to other stresses or is superimposed on them. Insect pests occur and multiply wherever trees grow, but it often appears that there are more kinds of pests at higher population levels on urban trees than under forest conditions. Yet, even this phenomenon has not been studied, nor has the economic impact of losses and damage or even the cost of control of shade-tree insects been assessed or tabulated. The monetary value of shade trees themselves is controversial. Thus it is difficult to show in economic terms how urgent the need is for adequate basic and applied research on tree insects even though it is obvious to those who work with them.

Existing methods of insect suppression on shade trees rely primarily on toxicants that are considered hazardous, objectionable to the public, unfavorable to the environment, expensive, and time-consuming to apply. Insect-control measures have been applied intensively to shade trees. Major pests usually require the application of pesticides annually. Minor pests are important and are frequently controlled when they increase to seriously damaging levels in very critical local situations. Moreover, people usually are not willing to tolerate even low populations of pests on valuable landscape plants.

Even with intensive use of insecticides, shade tree insects are highly destructive. Despite on-going control programs for major pests over the past 30 to 50 years, the transmission of Dutch elm disease by elm bark beetles has decimated our elms. The red pine scale has eliminated the use of red pine for watershed protection and ornamental plantings south of its natural range. Honeylocust has become pest-ridden since its general acceptance in widespread landscape use. Pine tip moth is still a scourge of two- and three-needled pines. White peach scale has raised havoc with flowering cherry trees developed for street and park plantings. The gypsy moth has killed thousands of oaks and other trees in the Northeast. During the 1960s in the Buffalo-Niagara Falls area, horned oak gall killed hundreds of pin oak trees. In Virginia and in Philadelphia the hemlock woolly aphid has appeared recently and is spreading. There are many other examples of insect depredation that could be cited, most of which have been given little attention publicly.

There is, therefore, ample justification for investigating new ways to minimize both the destructiveness of insect pests and the widespread use of toxicants. Insect-resistant trees would provide one ideal answer. Considerable research work on agricultural crops has shown that insect resistance can be an effective means of controlling insects. Painter *(1966)* cited a number of successful examples: Hessian fly on wheat, European corn borer, corn earworm, and spotted alfalfa aphid. Gerhold *(1966)* has reviewed and summarized indications of insect resistance and resistance mechanisms that have been reported for forest trees, and Callaham *(1966)* has evaluated their potential.

Theoretically and practically, insect resistance found in forest trees should be equally effective in shade trees. However, most of the forest trees that have been studied, such as black locust, conifers, poplar, walnut, and willow, are avoided or used only occasionally as ornamental trees. Further, it is doubtful that successes like those with agricultural crops could be achieved as rapidly with forest or shade trees. Nonetheless, past achievements have contributed much to our understanding of basic principles, factors and mechanisms of resistance, and research methods. There is an excellent opportunity to explore and investigate this new approach to insect control.

## DEFINING RESISTANCE

Insect resistance in its entirety has been treated thoroughly by Painter *(1951)*. He defined resistance as a threefold mechanism. One or a combination of any three elements is present in most cases of resistance that have been well-studied: (1) *non-preference*, plants not selected by insects for oviposition, for feeding, or for shelter; (2) *antibiosis*, an adverse effect of the plant on the insect or on its biology; and (3) *tolerance*, the ability of the plant to withstand infestation, recover, or repair itself to health and vigor.

It is important to distinguish between resistance and pseudoresistance. Pseudoresistance is defined *(Painter 1951)* as apparent resistance in potentially susceptible host plants resulting from (1) *host evasion*, where, for example, the host passes through its susceptible stage at a time when the insects are not active; (2) *induced resistance*, exemplified by growing the host under conditions where insects are not likely to attack it, because they prefer to feed on other available plants; and (3) *escape*, such as a lack of infestation in an ordinarily susceptible host due to temporarily low populations of the pest in the area.

Defining the terms of resistance is a much simpler task than defining resistance as it occurs in trees in nature. Throughout the history of entomology, workers have studied and compiled host-preference lists. Alternate- and multiple-host relationships have been described and related to anatomical, physiological, and biochemical characteristics of plants. Yet there are few records of even apparent resistance to insects in shade trees. The lack is due largely to science rejecting observations of plants *not* attacked as negative data unless compared to those that are attacked. In general, also, tree pests have been studied much less intensively than food-crop pests, so we still do not yet have sufficient understanding of the biology and habits of many shade-tree insects. Painter *(1966)* indicated that it is vitally important to have detailed knowledge about an insect's biology, especially feeding behavior and stimuli to which the insect reacts, to carry on a successful study of resistance.

Defining resistance in shade trees is a complex and difficult problem that requires careful integrated investigations, as the following examples illustrate.

It is a relatively common occurrence that certain individual spruce trees are free of spruce gall aphid even when their branches overlap and are intertwined with infested trees. I have observed this in Massachusetts and New York. Thielges and Campbell *(1972)* reported on studies in progress in Ohio on selecting and breeding spruce to avoid spruce gall aphid. From controlled crosses among three resistant and four susceptible trees, they hoped to test the hypothesis of single-gene control of aphid resistance. They suggested two possibilities to explain the resistance mechanism: (1) physical barriers to aphid stylet penetration on gall-free trees; and (2) chemical compounds produced by the plant in response to stylet penetration that were unfavorable to the aphids. They reported no significant differences between dates of growth initiation of galled and gall-free trees, concluding that gall-free trees are not "escapes" that grow at a time not favorable to the aphid.

However, I observed a situation to the contrary in New York, and it suggests pseudoresistance of the host-evasion type as defined by Painter. Of four large trees in one location, three were infested annually with many galls while one had none. Normally, on the one tree, bud break and new growth occurred later than on the three infested trees. In one of the 5 years of observation, those three trees produced no galls, and the gall-free tree became severely infested. The weather that spring was unusual. New growth of the three trees developed prior to the onset of insect activity, which occurred as the gall-free tree initiated new growth. Until that year the gall-free tree appeared

resistant. This type of resistance, nonetheless, might have some practical value in regulating spruce gall aphid populations.

Vivani *(1966)* cited an example of induced resistance. The leafroller *Byctisus populi* was found to prefer the thin-leaved poplars to the thick-leaved individuals where the two forms were growing together and the insects had a choice. However, when thick-leaved poplars were the only hosts available, they were readily infested by the leafroller. Growing the two types together induced insect "resistance" in the thick-leaved trees.

An example of "escape" pseudoresistance may be explained by mating and "brood" habits of the Japanese beetle. Where numerous kinds of highly susceptible hosts occur together and beetle populations are not high, certain trees may be damaged severely while others escape or have very few beetles. This does not necessarily occur on the same trees each year. Trees appear to be colonized initially at random by the beetles. They attract increasing numbers of adults to their host trees while nearby susceptible plants not occupied are ignored. Thus in any given year those trees that escape infestation might appear to be resistant.

There may be many instances where true genetic resistance to shade-tree insects is exhibited in nature. But they are seldom reported or sufficiently documented. For example, in a devastating infestation of pin and red oaks by horned oak gall in the Buffalo-Niagara Falls area of New York in the 1960s, I observed one live pin oak completely devoid of galls growing among many other oaks dying from contiguous gall formations along all branches and twigs. This tree may have manifested natural resistance to horned oak gall. Painter *(1966)* has stressed that any evidence of resistance in trees will certainly be found during extensive insect outbreaks. For substantiation, however, very careful investigations would be necessary to demonstrate true genetically controlled resistance.

It may be that insect resistance in trees is more real than apparent. Gerhold *(1966)* stated, "the existence of heritable insect resistance (in forest trees) can hardly be doubted, and one gets the impression it can be discovered in any species if only the search is diligent enough"; but he added, "In most cases, the degree of usefulness has yet to be demonstrated, largely because such long and extensive experiments are required." With shade trees, we are still in the earliest stages of finding and identifying insect resistance. Thus, it is most difficult to predict the feasibility of utilizing this as an effective tool in the foreseeable future. I am inclined toward the view of Vivani *(1966)*: "the chance of selecting improved trees for insect resistance is indeed less than it would seem to be on the basis of preliminary observation and consideration."

## PROBLEMS IN DEVELOPING RESISTANCE

One limiting factor in finding natural insect resistance in existing shade-tree plantings is horticultural diversity. A wide collection of genera, species, varieties, and cultivars is normal for landscape plantings, including exotic as well as native trees. There are relatively few individuals of any one type to express the genetic potential of the species. Unless the resistance is genetically dominant, occurring in many individuals, it is less likely to be found in existing trees. In contrast, there is more genetic and less horticultural diversity represented in agricultural crop plants and forest trees than in shade trees. Forests and woodlands contain mixtures of mostly native species in stands of many individuals. Forest production tends toward a monoculture of thousands or even millions of seedlings of a species.

In utilizing resistance, once discovered, resistant trees could supplant entire forest stands, but only a relatively small percentage of the total plant materials in

ornamental plantings. However, shade trees have an advantage with the increasing use of selected cultivars. Where insect resistance can be developed, it could be perpetuated indefinitely by vegetative propagation. This is a strong argument for finding and developing resistance even though it would solve only one or a few problems in a vast complex of many. In protecting shade trees, every means of preventing insect depredation is needed. Resistance could be utilized and could help, although it may not be generally applicable as a method of controlling shade-tree insects nor measurably reducing the overall use of toxicants.

A second problem in developing insect resistance in shade trees is the diversity in the insect fauna. Each kind of shade tree has a complex of major and minor pests associated with it. Trees such as elm and oak, which have been grown widely for centuries, have long lists of associated pests. As new trees come into general use, the list of pests grows with time and the number of plantings. Thornless honeylocust serves as a good example. Initially it was relatively pest-free, but common problems now include mimosa webworm, pod gall midge, honeylocust mite, thornbug, an eriophyid mite, and, more recently, honeylocust plant bug. Developing resistant trees against major pests case by case is helpful, but it is safe to assume that trees resistant to one pest may be susceptible to other pests. Borrowing an example from plant-disease studies, elms selected and propagated for resistance to Dutch elm disease have been all but eliminated by phloem necrosis where it has occurred.

Another problem in studying resistance is the fluctuation of major and minor pests of shade trees in time or space. They may fluctuate also due to changes in cultural practices. For example, European elm scale was a serious problem on elm prior to the use of DDT for elm leaf beetle and elm bark beetle control, yet was almost nonexistent on sprayed trees until DDT was banned. At the same time, the use of DDT resulted in severe damage by mites and aphids, which were minor pests prior to the DDT era.

Insect pests also fluctuate due to the kinds of trees that are planted. On new plant introductions, endemic or even rare pests may increase to become major problems. For example, when red pine was planted south of its natural range in Connecticut, New York, and New Jersey, the red pine scale developed to devastating proportions. No pesticidal control was found or developed, and red pine was eliminated by cutting and burning. In California, Indian laurel fig was introduced by the nursery trade as an ideal tree for urban planting. Subsequently the Cuban laurel thrips become a problem. It was 3 years before control measures were developed *(Bell 1969)*. Many more similar examples could be cited.

Fluctuations in the distribution and spread of endemic species will occur as man continues to transport them to new geographical habitats throughout the world; thus, new pest problems can be expected on already existing plants in any given area. The rate of fluctuation could certainly be expected to change more rapidly than the long slow process of developing insect resistance pest by pest and host by host. A period of many years and a great deal of research are required for implementation of insect resistance to displace significantly the need for insecticides. However, over an extended period of time, the development of insect resistance could alleviate some of the pest problems that afflict shade trees and eventually reduce some uses of chemicals.

A theoretical consideration in a study of resistance is the genetic ability that insect populations have to adapt and evolve their physiology and behavior. Over the 100- to 200-year lifespan of some shade trees, such evolution is likely to be expressed. Should resistance to one species of insect be established genetically within a host plant, vegetative propagation of the cultivar would theoretically preserve the genetic resistance in the tree.

The insect, however, living on other nonresistant individuals of the host, would genetically have the capability for change and adaptability, suggesting that the resistance in the tree might be of limited duration. However, Painter *(1951)* has cited cases to indicate that resistance should be permanent. Yet Campbell *(1966)* reported an interesting study with the forest tent caterpillar, providing evidence that physiological-genetic diversities in feeding do occur in the Lepidoptera. Along with reference to earlier work on spruce budworm, he showed that large variations in certain physiological characters of the insect were controlled genetically and were fundamental to numerical fluctuations in the insect populations.

One of the most critical factors limiting the development of insect resistance as a practical approach to insect control is the lack of sufficient research resources. Current manpower and funding are minimal even for investigating existing insect problems *(Weidhaas 1972, Campbell 1974)*. It is essential to provide remedies for insects that are already causing damage and are a threat to established shade trees. Yet there is a need for long-range innovative research on basic problems and the development of new methods and approaches to pest problems.

The impact of the newly amended federal pesticide law (FIFRA) has greatly aggravated the situation. Many pests no longer can be treated with insecticides that have been used effectively and safely for many years. New control measures must be developed to fill the void. Thus existing research resources must be applied to solving immediate critical problems.Where then will the manpower and financial support be found to study the intricacies and complexities of insect resistance where applicable results can hardly be expected until some distant time in the future? Which agencies or institutions are willing to support the long-range research needed to develop resistance? More practically, who would be willing to commit a career to research that might require 15 to 50 years of effort to show meaningful results, when professional and peer status, salaries, and promotions are evaluated on the basis of prolific publication of immediately applicable results from 3- to 5-year research programs?

## SUMMARY AND CONCLUSIONS

Theoretically, host resistance to insects is an ideal method for protecting long-lived valuable shade and ornamental trees in metropolitan landscapes. Realistically, it is a promising goal for the future much like the use of parasites and predators, pheromones, juvenile hormones, attractants and repellents, and certain cultural practices. Practically, in view of existing and foreseeable research resources, it is attainable only to the extent that a few individual cases of resistance may be developed and utilized in the future through on-going research programs.

There are indications that resistance to insects does occur in shade trees. There is evidence of resistance, and resistance mechanisms have been described, in forest trees. In agricultural production there have been some successes in applying host resistance. Therefore, there is promise of developing resistance to insects in shade trees. However, where host resistance has been successful in agriculture, the unit value of the crops has been small and the acreage large *(Painter 1951)*. With shade trees, the unit value is high and the acreage, or number of individual trees, is relatively low. In more than 50 years of research with agricultural crops, successes have been relatively few. Host resistance to shade-tree insects has yet to be discovered and described. The finding and development of resistance to the point where it can be applied in pest-management practice for shade trees is an extensive long-range research process.

Practically, utilization of insect resistance does not appear to be feasible as a major method of controlling insects nor a means of reducing measurably the over-

all use of toxicants. Current research resources for entomology are already woefully inadequate to meet the needs of ongoing programs and to solve immediate insect problems. Insect resistance has been historically of very low priority in tree-selection and breeding programs. Research efforts have been and now are aimed primarily at esthetic values of form, color, flowering, size, and the like; functional values such as shade, noise abatement, pollution abatement, and screening; and adaptation or tolerance to climatic, edaphic, and architectural influences. The diversity of plant materials and the vast array of insect species associated with them are awesome. Since insects are one of the more readily controllable stress elements in urban areas, perhaps assigning low priority to resistance to insects in research is appropriate and acceptable. If so, we must rely primarily on insecticides and continue to develop their effective and safe use. It is essential to protect and preserve existing trees and those better trees developed in tree selection and breeding research.

As arboricultural research moves forward, however, insect resistance should be explored and included in investigations wherever possible. Great strides have been made in genetics, biochemistry, ecology, population dynamics, and improved plant materials for landscapes. There is an opportunity, through existing integrated research programs, to explore insect resistance in shade trees and gradually acquire basic information. We hope that adequate research will be forthcoming to carry on the long-range development of insect resistance in the future as a supplemental method in pest management. In the meantime, indications and observations of potential insect resistance in shade trees should be recorded, studied, evaluated, and reported. Existing research programs on tree improvement, selection, and breeding should include observations and studies of potential resistance to insects. At least, when new varieties and cultivars are developed, they should be evaluated in relation to their susceptibility to major insect pests.

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# A LANDSCAPE ARCHITECT'S VIEW OF BETTER TREES FOR URBAN SPACES

*by* PAUL GARDESCU, *Landscape Architect and President, Sasaki Associates, Inc., 64 Pleasant Street, Watertown, Mass.*

*ABSTRACT.* Urban landscape architecture has a strong tradition for the importance of planted open space as an integral part of the city. There is also a strong tradition relating the city landscape to the surrounding region through the use of indigenous plant material. Trees are used as a design material in creating landscaped space. Tree selection is made for overall effect rather than individual characteristics. Plant lists, a primary source of information for the landscape architect, in general do not include cultivars or clones. An overriding factor, however, is availability of quality material. The emphasis in providing better trees for urban spaces is on improved growth and handling of suitable trees rather than on development of additional cultivars.

IN DESIGNING WITH TREES for urban areas, the landscape architect draws on a tradition that underscores the importance of the planted landscape as a complement to the constructed urban world. There is also a strong tradition of recognizing the natural features of an area and of trees indigenous to a region. This tradition reaches beyond the mere use of planting for embellishment and fascination with the exotic by relating the city open space with that of the surrounding natural countryside.

The use of trees in the urban area is related to the nature of the space and activities that take place. These areas range from large parks or natural preserves to plazas and tops of structures. The sources of information about trees, the quality and quantity of available material, and the landscape construction industry strongly dictate the selection and use of trees.

Selection of particular tree species or cultivars is of secondary priority in the design process, coming after consideration of overall effect, creation of site conditions that mollify the horticultural drawbacks of urban sites, and the obtaining of well-grown material.

As a general thesis, I propose that using better trees for urban areas involves, first, better growing and handling of known varieties, and second, the development of new cultivars.

A landscape architect looks at trees in the city from a point of view somewhat different from those of the horticulturist and the arborist. In large part this stems from the landscape architect's concern with space as a central element of de-

sign, trees being one of the materials to be used.

## HERITAGE OF LANDSCAPE DESIGN

In making judgments, I find it interesting to compare views held 50 and 100 years ago. Consider the views of that mentor of American landscape architects, Frederick Law Olmsted. A hundred years ago this designer of Central Park proclaimed the major role that landscaped parks, drives, and streets had in creating a beneficial urban world. In 1870 he wrote:

> "The park should, as far as possible, complement the town. Openness is the one thing you cannot get in buildings . . . We want a ground to which people may easily go after their day's work is done, and where they may stroll for an hour, seeing, hearing, and feeling nothing of the bustle and jar of the streets, where they shall, in effect, find the city put far away from them. We want the greatest possible contrast with the streets and the shops and the rooms of the town which will be consistent with convenience and the preservation of good order and neatness. We want, especially, the greatest possible contrast with the restraining and confining conditions of the town, those conditions which compel us to walk circumspectly, watchfully, jealously, which compel us to look closely upon others, without sympathy. Practically, what we want most is a simple, broad, open space of clean greensward, with sufficient play of surface and a sufficient number of trees about it to supply a variety of light and shade. This we want as a central feature. We want depth of wood enough about it not only for comfort in hot weather, but to completely shut out the city from our landscapes."

The rural and pastoral landscape was not anti-urban in concept, but was conceived as a necessary foil to urban activity and, more important, such landscapes were to be integrated into the fabric of the city.

Related to this advocacy of public parks was a call for planted streets. Olmsted *(1870)* wrote:

> "The change both of scene and of air which would be obtained by people engaged for the most part in the necessarily confined interior commercial parts of the town, on passing into a street of this character after the trees had become stately and graceful, would be worth a good deal. If such streets were made still broader in some parts, with spacious malls, the advantage would be increased. If each of them were given the proper capacity, and laid out with laterals and connections in suitable directions to serve as a convenient trunk line of communication between two large districts of the town or the business centre and the suburbs, a very great number of people might thus be placed every day under influences counteracting those with which we desire to contend."

Going back a bit farther, we find that great horticulturist and landscape gardener, Andrew Jackson Downing, championing American trees for American cities. In promoting a knowledge of beautiful trees and plants, Downing *(1851)* called attention to: (1) "what private individuals may do"; (2) "what the nurserymen may do"; and (3) "what the Horticultural Societies may do." He also espoused an avoidance of those foreign fads, the "odorous ailanthuses and filthy poplars" *(1852)*. He praised the American elm and silver maple with these words *(1847)*:

> "They have, to recommend them, in the first place, great rapidity of growth; in the second place, the graceful forms which they assume; in the third place, abundance of fine foliage; and lastly, the capacity of adapting themselves to almost every soil where trees will thrive at all." He went on to say: "Select the finest indigenous tree or trees; such as the soil and climate of the place will bring to the highest perfection. Thus if it were a neighborhood where elm flourished peculiarly well, or the maple, or the beech, we would directly adopt the tree indicated."

The sugar maple, native oaks, tuliptree, linden and magnolia are all cited for "a grand and striking effect." Great thoughts, no fussing with purple- or yellow-leaved genetic sports, no meager apologies for trees to cower under the omnipotent power lines.

Both Olmsted and Downing thought large and laid claim to plan and plant landscapes that would have a grand scale as part of a city. They recognized the use of trees for form-giving and ornamental effect, and the need to balance these two aspects.

In present practice, this sense of the

urban scale is what often separates the professional and the amateur. The landscape architect may analyze a situation and conclude that it needs the unification of a line or group of dense-headed shade trees. The garden club or even the horticulturist might only see the chance to embellish an area with a collection of ornamental novelties.

## RECENT LITERATURE ON DESIGN OF URBAN SPACES

If you cannot get hold of a good live landscape architect to declaim on the professional mysteries, there are several good discussions of the contemporary landscape architects' approach to design of urban spaces that put tree selection into perspective. Two outstanding books on the subject are Lawrence Halprin's *Cities (1972)* and Robert L. Zion's *Trees for Architecture and the Landscape (1968)*.

Halprin's book treats the whole gamut of urban landscape design. Green space is seen by him as contact with nature, which everyone should be able to enjoy, and open space as a key element in providing an environment for ". . . those chance occurrences and happenings which are so vital to be aware of—the strange and beautiful which no fixed, preconceived order can produce. A city is a complex series of events."

Halprin touches on the formal and naturalistic uses of trees and the special techniques employed in planting, protecting, and maintaining trees in paved spaces. He lists twelve trees for use in the city. Replete with photographs, Halprin's book is an excellent exposition of contemporary urban landscape design. It clearly illustrates the use of trees as a design material, and as only one of the many materials to be considered in the design of an urban space. Hence, it underscores a very basic attitude towards the selection of trees.

Robert Zion's book is—as its title, *Trees for Architecture and the Landscape*, notes—focused on trees. Though it only touches design issues, it is a complete compendium on tree selection. After illustrating the seasonal character of some 55 trees in (rural situations), he covers practical considerations, including protection of existing trees, buying and planting trees, and the special considerations for street trees, rooftop planting, and other special effects. He discusses design considerations noting:

> "If one general or all-inclusive counsel is to be set down here for the layman, it is this: *it is essential to keep the tree in its proper perspective*; it is not the essence of landscape architecture and should be regarded only as an embellishment—as furniture with which an outdoor room can be enhanced. Without denying the beauty and fascination of the tree in the landscape, the laymen should be cautioned against confusing the tree with the design itself."

Zion then provides design data for some 50 trees, many shown at commercial nursery size. A limited number of cultivars are noted in the discussion of species. The last section of Zion's book is a list of trees organized by states and classified by various design attributes. The classifications include "Trees for the City," categorized for usefulness by "For Wide Streets," "For Medium Streets," and "For Suburban Streets." The lists are extensive, although some selections are not commercially available. They give, however, a good sense of the very large range of material available even for the rigors of the city site.

In addition to the urban design considerations noted above, there are many studies on environmental considerations and on public policy dealing with trees. An example of the first is the recent *Plants/People and Environmental Quality*, by Gary Robinette *(1972)*, published by the U.S. Department of Interior. This includes an extensive bibliography and covers the whole range of environmental effects on and by trees. Surprisingly, however, it does not include lists of trees for urban areas. In the public policy domain there is the excellent monograph, *Trees in the City*, prepared by Charlotte Bingham for the American Society of Planning

Officials *(1968)*. It covers municipal regulations and planning as well as promotion of planting, and has a good but brief coverage of the public aspects.

## LANDSCAPE ARCHITECTS' SELECTION OF TREES

This brief survey of design literature leads into a key factor of the basis for tree selection by landscape architects—that is, where does he get information? Obviously, landscape education lays a foundation, and particular office practice provides further guidance. As noted above, however, tree selection is but a small part of the many complex considerations in the design of urban landscape. Therefore, reference books, articles, and information from state agencies and private institutions form a significant source of specific additional information.

The sources of information are limited. Depending upon one's education, Donald Wyman's *Trees for American Gardens (1965)*, or other lists, are used for handy reference. There are also many special lists such as those published by power companies, directed at certain specific goals such as trees that are compatible with overhead power lines. Local state and city agencies and arboretums are consulted as to their recommendations. Our own office practice supplements this with field surveys of a metropolitan area to see what has been proven to do well and what shows chronic problems.

A useful way of reviewing the current basis for urban-tree selection is to compare a few of the current published lists. A detailed review of such lists will not only identify specific reccomendations but also reveal in part how material is categorized, hence, thought about. Size, form, soil tolerance, shade tolerance, hardiness, and various ornamental characteristics are classifications usually used. In my table showing brief comparisons of some available lists, these classifications have been omitted for brevity.

In comparing lists, we quickly see the trees commonly recognized as suitable for urban use and the vastly larger group of limited recommendation. Admittedly, my table mixes lists prepared for regions with ones with national coverage. Also, one list will include cultivars by name while another will note that selected cultivars should be used without giving specific names. Much of the more exotic material is, in fact, not commercially available. The purpose of such a tabular comparison, however, is to demonstrate the fairly wide range of material available for consideration and incidentally the diversity of opinion that is expressed through the recommendations in such lists.

In plant selection there are certain methodologies that imply that choices can be almost entirely a deductive process. The assumption is: if the input criteria are sufficient, there are one, two, or three trees that will come out of card-sorted characteristics. I happen to believe that selection for good planting design is much more an inductive and associative art, and that classification by characteristics can only be used as a first rough-sorting technique.

In my table the entries in the first column are from Donald Wyman's *Trees for American Gardens*, which is a standard reference because of the generally useful descriptions. Though it does list cultivars, the supply of these is limited. His cross-classification by form, color, special uses, etc. is helpful in reminding one of additional trees that might be considered. It is also a reference easily available. In my table only the "Trees that Withstand City Conditions" are included. His additional lists for planting along streets and in other areas provide more material for consideration, but I have arbitrarily omitted his recommendations for the other situations in this comparison.

Entries in the next column are from another extensive reference, the recent monograph *Transit Planting: A Manual* by The American Horticultural Society

Table 1.—Number of species and clones recommended within selected genera as urban trees—by different authors

| Genus | Number of species and clones[1] recommended by— | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Wyman | Am. Hort. Soc. | Zion | Halprin | Taylor | Enright | Bartlett | Boston Edison |
| *Abies* | 1 | 2 | — | — | — | — | — | — |
| *Acer* | 5 | 5 | 1 | 1 | 2 | 2 | 5 | 8 |
| *Aesculus* | 1 | 2 | 1 | 1 | — | — | — | — |
| *Ailanthus* | 1 | — | 1 | 1 | 1 | 1 | — | — |
| *Albizzia* | 1 | — | — | — | — | — | — | — |
| *Amelanchier* | 1 | 1 | — | — | — | — | — | 1 |
| *Aralia* | 1 | — | — | — | — | — | — | — |
| *Araucaria* | — | 1 | — | — | — | — | — | — |
| *Bauhinia* | — | 1 | — | — | — | — | — | — |
| *Betula* | — | 3 | — | — | — | — | — | — |
| *Brassaia* | — | 1 | — | — | — | — | — | — |
| *Carpinus* | — | 2 | 1 | 1 | — | — | 2 | 2 |
| *Carya* | — | 1 | — | — | — | — | — | — |
| *Catalpa* | 1 | 1 | — | — | — | 2 | — | — |
| *Celtis* | 1+ | 3 | — | — | 1 | 1 | — | — |
| *Cendrela* | 1 | — | — | — | — | — | — | — |
| *Cercis* | — | — | — | — | — | 1 | — | 1 |
| *Ceratonia* | — | 1 | — | — | — | — | — | — |
| *Cladrastis* | — | — | — | — | — | — | — | 1 |
| *Cornus* | — | 2 | — | — | — | 2 | 1 | 4 |
| *Crataegus* | 3 | — | 3 | — | — | 3 | 2 | 2 |
| *Diospyros* | — | — | 1 | — | — | — | — | — |
| *Elaeagnus* | 1 | — | — | — | — | — | — | 1 |
| *Euonymus* | 1 | — | — | — | — | — | — | — |
| *Ficus* | — | 1 | — | — | — | — | — | — |
| *Fraxinus* | 3 | 2 | 1 | 1 | 4 | 2 | 2 | 1 |
| *Ginkgo* | 1 | 1 | 1 | 1 | 1 | 1 | 2 | — |
| *Gleditsia* | 1 | 1 | 1 | 1 | — | 2 | 1 | 1 |
| *Gymnocladus* | — | — | — | — | — | 1 | — | — |
| *Halesia* | — | 1 | — | — | — | — | — | 1 |
| *Ilex* | — | 2 | — | — | — | — | — | — |
| *Juglans* | — | 1 | — | — | — | — | — | — |
| *Koelreuteria* | 1 | 2 | — | — | — | — | 1 | — |
| *Larix* | — | 2 | — | — | — | — | — | — |
| *Liquidambar* | — | 1 | — | — | 1 | — | — | — |
| *Liriodendron* | — | — | — | — | 1 | — | — | — |
| *Magnolia* | 3 | 2 | — | — | — | 1 | — | — |
| *Malus* | 1+ | 1+ | 1+ | — | — | 17 | 3 | 4 |
| *Melia* | 1 | — | — | — | — | — | — | — |
| *Metrosideros* | — | 1 | — | — | — | — | — | — |
| *Morus* | — | — | 1 | — | — | — | — | — |
| *Nyssa* | — | — | — | — | — | — | — | 1 |
| *Olea* | — | 1 | — | — | — | — | — | — |
| *Ostrya* | — | 1 | — | — | — | — | 1 | 1 |
| *Phellodendron* | — | 1 | — | — | 1 | 1 | 1 | 1 |
| *Picea* | 1 | 3 | — | — | — | — | — | — |
| *Pinus* | — | 5 | — | — | — | — | — | — |
| *Pittosporum* | — | 1 | — | — | — | — | — | — |
| *Platanus* | 1+ | — | 1 | 1 | 1 | 3 | 1 | 1 |
| *Populus* | 3 | 5 | 3 | — | — | 1 | — | — |
| *Prunus* | — | 4 | — | — | — | 2 | 2 | 2 |
| *Pyrus* | — | 1 | 1 | — | — | 1 | 1 | — |
| *Quercus* | 3 | 5 | 1 | 1 | 4 | 1 | 8 | 2 |
| *Rhamnus* | 1 | 1 | — | — | — | — | — | — |
| *Robinia* | 1 | — | 1 | — | — | — | — | 1 |
| *Salix* | — | 4 | 1 | 1 | — | — | — | — |
| *Sophora* | 1 | 1 | — | — | — | — | 1 | 1 |
| *Sorbus* | — | — | — | — | — | — | — | 2 |
| *Syringa* | — | 1 | — | — | — | — | — | — |
| *Tilia* | 2 | 2 | 1 | 1 | 3 | 1 | 2 | 2 |
| *Tsuga* | 1 | — | — | — | — | — | — | — |
| *Ulmus* | 5 | 2 | 1 | — | 2 | 3 | 1 | — |
| *Zelkova* | — | 1 | 1 | 1 | — | — | 1 | 1 |

[1] Where authors are indefinite but apparently recommend more than one species, 1+ is shown.

It lists trees, shrubs, and ground covers suitable for urban conditions, with classifications by climate zone as well as by size, growth rate, form, features, and special characteristics.

Following these are three short lists comprising recommendations of Zion, Halprin, and A. D. Taylor. Taylor's work, though over 50 years old, still is one of the most comprehensive and commonsense works on landscape gardening *(1921)*.

The next recommendations are from L. Enright's *Woody Plants for Landscape Use*, a typical working list useful for quick office reference *(1955)*.

The recommendations made in the *Street Trees Study for the District of Columbia*, by F. A. Bartlett Tree Expert Company, is an example of a list developed around the experience of a particular locality.

The final listing from *Trees in Your Community* is representative of handbooks provided by public service companies, and includes some species not strictly suitable for urban conditions.

These lists demonstrate somewhat differing approaches in tree selection. Taylor and Halprin list the best few. This is an approach used by our own office, and it is reinforced by the generally limited supply of quality nursery material. The American Horticultural Society, Wyman, and Zion provide extensive lists and, as previously mentioned, some selections are not readily available. Enright's and Bartlett's lists are perhaps mid-range, and typify working lists used in the practice. All lists, of course, reflect selections in response to the horticultural problems of urban areas. There is a lack of usable evergreens. There is the lack of an equivalent for a large canopy tree to replace the American elm (Zion, like Downing, recognizes the design equivalency of the silver maple, provided the location is suitable to the weak-wood characteristic). The other feature worth noting is that, unlike much of the periodic literature, the lists generally do not name cultivars. Wyman discusses cultivars to a limited extent in his text, but generally does not cover clones and varieties. This has the effect, of course, of not suggesting the use of cultivars even when they are readily available.

## AVAILABILITY OF QUALITY TREES

There is perhaps an even more fundamental problem. Availability and quality are factors overruling recommendations in the various lists.

In most urban landscape situations, larger material must be used not only because it is expected to provide immediate effect, but because it is less subject to vandalism than small material. In addition, because maintenance by knowledgeable staff is very hard to get, trees that require a minimum of care need to be selected. Hence, trees of neat or predictable habit and well-formed through good nursery handling are mandatory.

Contractors' opinions are sought, and nurseries are checked both for information and for available stock. An early lesson is that the best academic advice is no help if no one can supply a given species in the size desired. The design process often requires contracting for trees that may be planted for one to several years later. This creates additional problems whether one wishes to obtain matched specimens or ornamental specimens.

However, in the selection process, the overall effect is most often of first priority, and not the use of a specific tree. At this point landscape architects can make arborists and horticulturists wince by their apparently casual attitude toward developed clones or even species—because the desire for matched blocks or for a well-formed tree (achieved through good nursery practices) often overrides considerations even of species selection.

I have seen professional park people bewildered by a landscape architect switching, for example, from maple to oak for a street planting because available maples were narrow, crowded, and poor

branched while there existed a well-branched, evenly matched block of oaks. In addition, the need to get large quantities of sizable trees through public bidding thwarts the consideration of using selected clones or varieties. This does not mean that the landscape architect is indifferent to the selection of better trees, but that he often has other things of greater importance to consider.

It is hard to emphasize sufficiently the problems of good nursery practice. Rapid turnover is a key element to commercial success, hence the large volume of builders' plants. These are the quick-growing, easy-to-propagate materials. On the other hand, it is disheartening to see beeches or tea crabapples so butchered by unskilled pruning that Norway maples or 'Almey' crabapples become the best selection of the day.

In a way there remains the need to develop trees with good form and naturally balanced habit of branching, both of formal and informal character. As an example, honey locusts not prone to narrow-crotched double-leaders would provide many more quality trees. But when one sees a good ornamental pruned to branch from one place like a pollarded willow, it eclipses all thought of developing better forms of trees, and underscores the need to get better nursery practice.

Likewise, nursery practice often leaves only a few trees of medium to large size that are not stunted by crowding. If the project warrants large material, there is often the problem that the only sources are the culls left over as blocks were sold. This type of problem becomes a major consideration in the actual execution of the work.

## CONCLUSION

In summary, this landscape architect's view is that—while there is obviously the desire to develop new cultivars—there is a far greater need to grow and market good-quality stock of already known species and cultivars. This is said to emphasize where the problems lie in supplying and selecting trees for urban landscapes.

One last aspect is worth noting. There is very little practical documentation dealing with special urban problems of tree growth. As an example, while container planting has been done for centuries, there is little applied research dealing with root-pruning or other maintenance techniques for trees in contained areas. Another problem deals with limited soil depth such as is encountered when planting over structures. Issues of providing a separate layer of drainage material or the use of a specially designed mix for areas as shallow as 12 to 18 inches could be immeasurably clarified by practical field research. This suggests that there is a special branch of urban horticulture that is in great need of collaboration among landscape architects, arborists, and horticulturists.

Urban areas must be planned and designed so they are hospitable to the growth of plants. Trees that will flourish or at least thrive under urban conditions must be identified, and their proper propagation and growth must be encouraged. Effective use of trees at an urban scale will continue to derive from a detailed experience with what will prosper, but their use will give us that experience with nature we all should have the opportunity to enjoy.

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# DESIGN CONSIDERATIONS IN THE SELECTION OF CULTIVARS FOR METROPOLITAN HIGHWAYS

*by* JOHN J. RYAN, *Director, Landscaping Bureau, New York Department of Transportation, Albany, New York*

*ABSTRACT.* The role of the highway landscape designer in developing appropriate plans for tree planting along metropolitan highways is discussed. The need to determine design objectives for each project is emphasized, and the design and visual considerations that must be taken in account for such a determination are explored.

## THE NEED FOR TREES

THERE IS A NEED for beauty in our lives that is just as essential to our spiritual and mental well-being as proper nutrition and clean air are to our physical well-being.

Thomas Jefferson, a man of wide-ranging interests, said: "Communities should be planned with an eye to the effect made on the human spirit by being continually surrounded by a maximum of beauty." This is a wonderful guide for us in our efforts to ensure that trees make a major contribution to beauty in our communities.

While trees are but one of the many things that hold beauty for mankind, they are undoubtedly one of the most important. They are beautiful and effective in various ways all seasons of the year. We can feel a relationship with trees—and a large tree doesn't overwhelm us the way a large or tall building does, because trees are on a human scale.

One of the many desirable attributes of a tree is its summer shade. This is different from the shade of anything else. It is constantly changing and has a filtered, light quality of immense esthetic appeal —particularly in urban areas where shade is often the heavy, solid shade cast by buildings.

In winter, the structure of the deciduous tree is revealed. You can see the trunk, the branches, the minor branches, and the twigs. Together they present a beautiful outline against the sky. One of winter's most delightful sights is a tree with snow lodged on its branches and twigs.

In spring, all deciduous trees have an appealing cover of unfurling, light green leaves. Then people are particularly glad to see this never-failing indicator of real spring. In the autumn, most deciduous trees indicate the passing of the season by changes in leaf color, some of which are spectacular and a source of joy.

## THE ROLE OF THE HIGHWAY LANDSCAPE DESIGNER

While developing an outline for this paper, I found that I couldn't present a well-rounded view of the highway landscape designer's function without straying into other fields or disciplines. I do not apologize for this. I believe that this is essential to demonstrate that solutions of the problems we are discussing are facilitated by an understanding of, and collaboration with, other relevant fields and disciplines. We are engaged in what must be considered as a team effort, and all of the several professional fields involved have important contributions to make.

The highway landscape designer should have, as his major objective, the esthetic improvement of the highway right-of-way and its adjacent areas. Beauty should be consciously sought, and appropriate design decisions made, in light of this objective. While trees will be of primary importance in these efforts, the providing of adequate space in which to plant is of equal importance.

In addition to concern for landscape matters, the highway landscape designer may also contribute to the highway design in such matters as the amount of right-of-way needed for effective landscape treatment, the slope ratio of cuts or fills, the treatment of retaining walls, the retention of parcels unneeded for actual highway construction and similar problems. Occasionally there will be an opportunity to preserve existing mature trees and so retain major landscape components.

The highway landscape designer must keep eight basic considerations in mind. All, with the exception of the first, are of equal importance in arriving at an optimum solution.

1. The overriding consideration in any highway landscape work is the *safety* of the highway user. This consideration is reflected by the appropriate setbacks of trees for the several classes of highways of varying legal speed limits, vertical and horizontal sight distances, and related engineering matters.
2. The designer is usually working in what might be called a horticulturally hostile environment and must do whatever is possible to lessen its influence.
3. The motorist using the highway who sees, or more accurately is aware of, the highway landscape treatment is driving between 30 and 55 mph and cannot be expected to be sensitive to fine detail or subtle effects. What he sees or is aware of are masses of trees or foliage and the space between the roadway and the planting. It would be doing the motorist a disservice to distract his attention with a spectacular floral display, although touches of color add to the subliminal effect of the landscape. In contrast, landscaping of rest areas can give greater attention to detailed effects.
4. The effect of the landscape work on the residents adjacent to the urban highway, or on the people employed along the area, must be taken into account. The pedestrians who use the sidewalks along the highway or on adjoining streets are also affected by the landscape development.
5. The designer must consider and evaluate the needs and potentialities of the area he is working on. Often the trees and other landscape elements comprise the only landscape in the area and are extremely important because of this.
6. The designer should consider alternate concepts for the landscape treatment of the highway right-of-way.
7. Appropriate contacts with the local governmental units must be made so that plans are developed with their knowledge and cooperation.
8. The project must be oriented to people —whether motorists, pedestrians, or adjacent residents.

Hopefully, as the above considerations are studied and determinations made, the designer will coincidentally start to develop a rational system for the selection of trees for the project rather than turning to lists or depending on personal likes or dislikes.

## GOVERNMENT POLICY DECISIONS AND FUNDING

All present here today are undoubtedly in favor of planting our urban highways. We can talk and talk, but nothing is going to happen until the appropriate government unit adopts and implements a policy of landscape development. A number, probably the majority, of the government units who build urban highways have already developed a policy of highway landscape development. When federal aid is involved, appropriate planting is encouraged by the Federal Government, but it is still up to the local government unit to decide how to use its highway funds.

Where there is no policy on the matter, and planting is not done, the community involved should demand a policy of appropriate landscape development and implementation of that policy. This policy should also provide for maintenance as well as for capital construction.

The funding of the work varies with the individual projects, and the only hard and fast suggestion which can be made is that the landscape development be funded in the same manner as the highway.

The project budget is best determined after some early preliminary planning. This will insure that there will be adequate funding for the level of development sought. Except in very unusual situations, no advanced or detailed planning should be done until the sources and amount of funding has been determined.

## RELATIONSHIP BETWEEN CLASSES OF HIGHWAYS

In the context of this discussion, the highway landscape designer must deal with two basic classes of highways: the suburban highway, and the urban expressway or arterial together with its service roads. The importance of the urban highways is overriding, but there must be recognition of the necessity for appropriate landscape treatment of the suburban highways and of portions of rural roads. The need for continuity of design between the two classes of highways must be recognized. This transition zone requires special recognition and treatment.

In the majority of situations along rural highways leading into the suburban and urban highways, there is no need for planting—except perhaps at interchanges and a few special situations. Proper mowing patterns and the natural regeneration of woody plants will provide exactly what is best. The most important thing here, and in urban areas too, is to remember that nature has veto power over anything we do.

## DESIGN AND VISUAL CONSIDERATIONS

After the decision to provide landscaping, the development of design concept alternatives should be the starting point of design for all projects. Occasionally this study will indicate that no planting is feasible for part or all of a project—due to costs, extremely harsh or hostile environment, or the potential for natural regeneration.

The designer should determine the effect he wishes to create on the site available to him and assemble his objectives and means of achieving them in written form supplemented by sketches, partial plans, and the like.

The great majority of urban arterials are at ground level, but a small and important percentage of the major arterials in the urban areas are either roadways

depressed below the level of the adjacent land or roadways elevated on columns or on fill. Usually both types, depressed and elevated, will have flanking service roads which are at ground level. All three categories—depressed, elevated, and ground level—call for somewhat different design approaches.

Sometimes in the depressed sections the combination of heat-reflecting retaining walls, lack of adequate space for planting, and steep slopes make the planting of trees impossible except at interchanges and along service roads. In such situations, the planting of the interchanges and service roads should be heavy to be sure that a definite landscape effect is achieved.

Where there is an elevated highway or interchange on piers or on fill, it is essential that the designer determine the amount of sunlight the plants will receive, especially during the growing season. On some projects this can be done by simple observation, but when the planting of a complex interchange is being considered, accurate information is needed. This information can be obtained by preparing a shadowgraph from sun-control data in such architectural references as Ramsey and Sleeper *(1970)*. A shadowgraph can be prepared for any time of day, any day of the year, and at any location to show the shadow cast by any object. Such shadowgraphs will often yield surprises, and you may find that it is possible to plant in the middle of a complex interchange because there is enough sunlight for plants to thrive.

The planting of trees on one side of the service roads is, for the most part, straightforward street-tree planting. Often there is considerable space between the service road and the main highway, which can be planted and which will be effective both from the man highway and from the service road. In such cases, the planting between the service road and the highway can be informal and heavy.

Often the same kind of trees are used for considerable length along the service road. There is no sound design reason to do this in every case. The designer should consider varying the species—from block to block or as necessary—to obtain a more interesting landscape effect.

Often there will be parcels along a major urban highway that are unused for highway purposes. Where these occur, they form an opportunity to design a small park or an open landscaped space with enough trees to give a feeling of depth, instead of a single row of trees.

Sometimes it is possible to plant on private property by permit, and so greatly increase the landscape effect. The conditions under which this can be done vary greatly, but this work should be considered where possible.

One of the persistent misunderstandings about the planting of trees and other woody materials along highways is that such planting will greatly help in reducing traffic noise. Sometimes the highway landscape designer is requested to plant trees for this purpose. A research project conducted for the Highway Research Board *(Gordon et al. 1971)* indicates that such planting has little or no value unless the planting is at least 100 feet in depth, dense, and at least 15 feet tall. Under these circumstances there may be a maximum reduction of 5 decibels, although visual isolation of the source may reduce a person's awareness of the noise to a greater extent.

## DESIGN CONSIDERATIONS IN TREE SELECTIONS

Often at this stage in a paper, one or several lists of trees are proposed for use in different situations. This offering of a predetermined list doesn't seem a professional approach to the problem. Also, the presentation of such a list would be particularly inappropriate for members of this audience who have as one of their main goals the development of new and better cultivars.

As no two projects or sites are identical, it is imperative that the designer

determine and assemble his own list for each project. The designer must keep his design objectives in mind in making his selection and choose those trees that will assist most in achieving the objectives.

While these comments are made on the assumption that the highway landscape designer doing a project has a sound background of knowledge and experience in using trees, there are bound to be instances in which the special expertise and knowledge of a professional arborist or similar expert should be sought. Cooperation and collaboration between the two fields of expertise are bound to be in the best interests of the project at hand.

The designer should not necessarily select or reject a new cultivar. He should discuss the matter with the apropriate expert and make a joint evaluation of the development, characteristics, and period of testing of the tree.

In actual practice it must be recognized that the designer is working on a specific project and that he must be pragmatic in his selection of trees. All of the experimentation and testing of new cultivars should have been done, so the project is not a testing field—except in the most unusual circumstances where it is clearly understood that the project is experimental in nature and where provisions have been made to replant the project if the experimental planting is not successful.

The following considerations are not necessarily in order of importance, because the relative importance will vary from project to project. The fundamental characteristics of the trees should be evaluated against the design requirements. However, the designer may choose to develop his own list—mental or written—of the characteristics he feels are important. The following characteristics are largely from a design viewpoint rather than from a horticultural viewpoint:

1. The anticipated size of the tree at various ages—say 5 years after planting, 10 years after planting, and at early maturity—as well as the effective life of the plant. It is essential to know this in order to carry out the designer's intent.
2. Deciduous or evergreen (coniferous or broadleaved).
3. Appearance and character of trees as related to trunk, branch and twig structure, and bark.
4. Density of shade. Important both from an appearance viewpoint and from the standpoint of whether planting grass, ground covers, or other plants under the trees will be possible.
5. The foliage color in spring, summer and fall, and the relative leaf-out and leaf-drop times. Great variation from species to species, and a characteristic of importance in certain projects.
6. Relative time of flowering, duration of period of bloom, and flower color of plants used in floral displays.
7. Fruit color, duration, and possible hazard or nuisance from tree fruits.
8. Location of overhead and underground utilities.
9. Size of material to be planted is sometimes limited by size of soil ball that can be handled—as on steep slopes and in narrow spaces between curb and sidewalk.
10. Capacity of tree to produce a branch and crown structure that provides adequate vertical clearance for pedestrians when used as a street tree and the eventual clearance as may be required on the street side for passenger cars and trucks. Some trees cannot provide such clearance without looking grotesque and misshapen when planted, although they may recover to a typical shape years after planting.
11. Availability of the trees in the sizes proposed. Size of tree may be guided, to some extent, by available funds.
12. Specification of nursery-grown trees meeting AAN (American Association of Nurserymen) Standards.

## RESEARCH AND DEVELOPMENT

The need for better trees for metropolitan areas is undisputed. A research and development program for this purpose is very timely.

The highway landscape designers will have a continuing interest in the program, and should be consulted on needs, evaluations, and some aspects of testing under field conditions.

If trees are going to be specifically developed for the usually harsh conditions of metropolitan areas, it would seem desirable that such trees receive special cultural treatment and be readily identifiable. Consideration should be given to having a special or specification designation in the nursery industry that would ensure special root pruning, special top pruning, and selection for quality.

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# ROLE OF CULTIVARS IN A ROADSIDE PLANTING AND MAINTENANCE PROGRAM

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*ABSTRACT.* Planting and maintaining roadsides requires flexibility in administration and operation. Financial and technical demands on these programs are ever-changing, and there is a continuing need for plants that, having specific qualities, will meet these changing demands. Controls and techniques of planting and maintenance are discussed, especially their effect on plant materials used. Existing rules and regulations can be modified to stimulate the use of cultivars, and an incentive program is proposed to stimulate their use.

SINCE THE INCEPTION of roadside planting programs more than 50 years ago, the persons in charge have been concerned with roadside esthetics and the types and sources of planting stock.

However, only in recent years has the highway engineer realized the overall significance of combining the engineering and esthetic qualities to produce an environmentally sound highway program. No longer is it a simple matter of designing and constructing an arterial highway between two points with consideration only for traffic demands. Curvilinear alignment in lieu of long tangent sections is now preferred as a means of adding beauty and fitting the highway into and not onto the landscape.

Much of the early roadside landscaping was justified on the basis of erosion control. Even as late as 1960 the solution to obtaining federal funds for highway landscaping was to stress erosion control, not beautification. Under this philosophy a cost/benefit ratio was feasible, and no agency could be condemned for spending public funds on beauty.

Recent studies, such as the one by Baker *et al. (1973)*, reveal the public's preference for trees, plantings, and a neat park-like appearance. Consequently, highway departments can now design, plant, and maintain roadsides for esthetic values without fear of public criticism.

Future travel modes are predicted to change drastically in the next 25 years *(Frost and Sullivan 1975)*. A decline in the use of the internal-combustion engine from the current high of 99 percent to a mere 14 percent by 1990 is forecast as the

diesel, Wankel, and other power plants come of age.

These authors also report that the use of mass transportation will increase and create a leveling-off of private auto use at approximately 118 million by 1990. These changes, I predict, will substantially alter the roadside atmosphere and permit the utilization of plants that have been considered too sensitive to roadside pollution.

Just which plants the designer may select for his roadside design depends considerably upon the policies of the specific state highway department. I shall briefly review current practices in the establishment and maintenance of roadside plantings, and offer some ideas about the role that cultivars may play in future roadside landscaping.

## PRESENT PRACTICES OF HIGHWAY DEPARTMENTS

### Planting Practices

All states have planting programs that are financed partly or wholly by federal funds. Programs under the Federal Aid Interstate Highway Act call for federal funding of 90 percent of the costs and state funding of 10 percent. Provisions of the 1965 Highway Beautification Act (Title III, Scenic Enhancement) provide for federal funding of 100 percent of the costs of vegetation establishment. There are also other ratios of financing that are not as attractive to the states. Under cooperative financing, the design and establishment of roadside plantings are closely reviewed and inspected by both federal and state agencies.

Pennsylvania has not restricted the roadside planting of trees to projects financed jointly or completely with Federal funds.

Each of Pennsylvania's 11 highway-engineering districts has a District Roadside Specialist. He directs the whole roadside program for his area—from design through establishment to maintenance. Through experience he acquires considerable knowledge that he uses in subsequent planting designs and in the selection of plants.

Most interstate and major-highway projects require detailed plans for the plantings, and these are prepared either by the Roadside Design Section of the Bureau of Design in the State (Harrisburg) office or by consulting landscape architects.

Unlike many states of the Northeast, Pennsylvania requires that roadside planting be contracted and established at the same time and under the same contract as construction of the road. There are the following administrative and operational advantages in this procedure.

1. Only one contract need be prepared and negotiated.
2. The details of proposed roadside treatments are presented and discussed in public hearings—not merely promised at hearings and then dropped because of indifference or financial problems of the administration, or for other reasons. The discussions may cause plans to be modified as needed and the changes incorporated into the construction contract. The value of such a procedure in this era of environmental awareness cannot be overemphasized.
3. The prime contractor invariably sublets the planting job, including the supplying of plants, to a qualified landscape contractor. The latter coordinates his planting and any other roadside operations with the road construction. Often, by the time the project is completed, many of the plants have been established for a year or more.
4. Planting operations do not require separate protection from traffic. In contrast, landscape plantings after road construction often delay or impede the travel of motorists.
5. When the highway is completed and opened, the landscaping treatment is often finished—thus providing the motorists more pleasing views than the barren wasteland of unlandscaped

roadsides that prevail until landscaping is completed under a separate contract.

Plantings after completion of highway construction and under separate contracts, which cover the entire project or a number of contiguous projects, also have certain advantages. These are:

1. The landscape designer can see the finished site conditions. Use and culture of the adjacent land may require screening or other changes in landscaping that may not have been anticipated. Such variations in desirable landscaping are almost impossible to design before the road is constructed unless the landscape designer fully understands highway plans giving profiles and cross-sections.
2. Contract execution and planting practices are somewhat more coordinated between landscape-oriented personnel —the landscape architect, landscape contractor, and landscape-inspection personnel. For example, there are probably fewer conflicts and delays in plant inspection, digging, storage, and establishment than when landscape contracts are sublet by prime contractors.
3. A period for plant establishment can be incorporated into the contract and used without delaying the completion of payment for highway construction.
4. Changes in planting stock or establishment methods can be negotiated directly with the prime contractor.

In Pennsylvania, plants for roadside plantings are inspected and "sealed" at nurseries by Regional Field Control Representatives before the plants are dug. Because there are only three such representatives in the state, nursery inspections are of high quality and uniformity. These representatives are given professional latitude to match nursery stock and planting sites—an invaluable procedure regardless of the contracting method. High-quality inspections at the nursery are important in preventing rejections of entire shipments of planting stock at planting sites.

Nursery inspection is also, I believe, the principal reason for increased plant survival since Pennsylvania adopted this procedure. Nursery inspectors can observe cultural practices and consider them in the selection of plants. They can reject as unsuitable for roadsides, plants that have been excessively fertilized, as indicated by their abnormal growth.

Digging practices are also a major concern. Though modern equipment for digging trees provides significant saving in labor and is of tremendous value to the nursery industry, it can jeopardize survival. I think that many plants, sites, or conditions are not adapted to such a digging technique. I believe that an evaluation of plants adaptable to mechanical digging is sorely needed. The nursery industry and equipment manufacturers should provide needed information on the results of different techniques and issue guides for digging specific stock under specific conditions. Perhaps the *AAN* (American Association of Nurserymen) *Nursery Standard* would be the appropriate outlet for publishing precautions and approved techniques in mechanical digging.

Nursery inspectors have the opportunity to discuss and review digging, balling, storing, and shipping techniques with nursery personnel. Unsatisfactory techniques can be determined then, and avoided, so later rejections may not occur and may not jeopardize the completion of scheduled plantings.

As I have learned much through discussions with nurserymen, I would urge all landscape designers to make at least one nursery inspection annually. Thus designers can become familiar with many of the new selections of plants for possible inclusion in subsequent designs and can also learn about changing techniques in producing nursery stock.

Standard forms, such as shown in figure 1, should be used for inspection reports to assure uniformity. If the nurs-

Figure 1.—Form used by the Pennsylvania Department of Transportation in inspection of plants, for roadside plantings, upon delivery to the planting site.

LD-6104 (8-72)
CC-0830-4800-0300

**PLANT MATERIAL**

**INSPECTION REPORT**

DISTRICT _____
COUNTY _____
SPECIFICATION YEAR (FORM 408) _____

Project or Agreement No. _____ Route _____ Section _____

Department Forces ☐ Contractor _____ Sub Contractor _____

Plant Material Supplier _____ Nursery _____

| ITEM NO. 808__ | PLANT NAME | SIZE | POTTED / BARE ROOT / B & B | QUANTITY | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | PLAN | This Delivery | ACCEPTED | Rejected (cause) (1-14) | Balan Du |
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Delivery _____ _____ Department Inspector _____
*(Date)* *(Time)* *(Name and Title)*

Date District Roadside Specialist Notified _____ Approved: _____
*(Roadside Specialist)*

**NOTE:** The Department Inspector shall complete this report in duplicate (front and back) for each shipment of material delivered. The District R de Specialist or his representative shall check this material and report before approving. The original copy shall be placed in the project file a d ve as quality documentation. The duplicate copy shall be retained by the Roadside Specialist and be placed in District Roadside files for refe e in conjunction with subsequent plant materials survival inspections.

D-6104 (8-72)
C-0830-4800-0300

## PLANT MATERIALS CHECKLIST

## AND/OR

## CAUSE FOR REJECTION

| YES | NO | |
|---|---|---|
| ☐ | ☐ | 1. Is plant material covered with burlap, canvas or other covering to prevent windburn and drying out in transit? |
| ☐ | ☐ | 2. Is "heating" or "sweating" by reason of tight packing or poor ventilation evident? |
| ☐ | ☐ | 3. Was the root system, of bare root stock, protected by moist material such as straw, hay or other mulches during transit? |
| ☐ | ☐ | 4. Is plant material properly identified by label? |
| ☐ | ☐ | 5. Does the plant size agree with size indicated on label? |
| ☐ | ☐ | 6. Are certificates attesting to insect or disease free plants furnished with this shipment, invoice, or order? |
| ☐ | ☐ | 7. Is plant material free of broken branches, mechanical wounds or other latent defects? |
| ☐ | ☐ | 8. Are Department metal seals, attesting to pre-inspection, affixed to the plant material? |
| ☐ | ☐ | 9. Does the ball size or root system meet the minimum "American Standard for Nursery Stock" requirements? |
| ☐ | ☐ | 10. Is the ball condition satisfactory? |
| ☐ | ☐ | 11. Are the balling and burlapping or root protection devices adequate to prevent damage to plants during handling? |
| ☐ | ☐ | 12. Were B&B plants handled by the ball during unloading and other handling operations? |
| ☐ | ☐ | 13. Was all plant material promptly and properly stored after delivery? |
| ☐ | ☐ | 14. Other condition(s) detrimental to plant survival noted as follows: |

eryman receives a copy at the time of inspection, subsequent misunderstandings will be reduced, and better handling practices will be the result, as he is therefore aware of the causes for rejection.

The nursery industry is providing increased amounts of container-grown plants that permit extending the planting season for many species and cultivars. Such extended seasons improve the chances of meeting completion dates on projects. Consequently, plants that are adapted to container-growing rank high on any designer's list.

Modern shipping methods permit direct shipments from the nursery to the planting site with minimal handling. The practice of heeling-in near the planting site is reduced or eliminated on many projects, and thefts of stock from storage areas are also reduced. Theft and vandalism are particularly common in urban-planting projects. While barbed or thorny plants are less likely to be stolen or vandalized, they cause discomfort to the contractor's personnel during planting and subsequently to maintenance personnel who have to remove wind-blown debris lodged in the plants.

Before roadside trees are planted, site conditions should be thoroughly analyzed—in particular:

1. Underground and aerial utilities may not be situated as shown in original plans, and the "as-built" plans should be studied so any necessary changes in planting plans can be made.
2. Use of adjacent property may not be compatible with the selected species or its location, or the planting or preference of the adjacent-property owner may warrant a change in the planting plan.
3. Changes in soil conditions or water table, as the result of construction activities, may make desirable a considerable modification of the planting plan.

In my opinion—based on analyzing probable causes of mortality—more tree have died in roadside landscaping fro too deep planting than from any othe single factor. There are admittedly sev eral differing views on the proper dept for best survival. Alban and Reisc *(1973)* noted that heavy clay soils, e pecially in fills or under compaction, hav extremely poor drainage. They recom mend that in such conditions trees shoul be planted so one-third to one-half of th ball depth is above existing ground leve the trees should be adequately guye and the soil should be adequate mulched to prevent drying of roots.

Pirone *(1972)* stated that: "Expe enced arborists have found that if a tr is set a bit higher in its new location tha in its former one, the chances of co tinued good growth are increased. It is well known fact that trees set too deep will not thrive and may even die within few years." However, where planting sit consist mostly of loose rock or oth coarse fill, creating extremely dry conc tions, I have seen successful plantings which the tops of the root balls were s 6 inches below the finished grade. Tho sites do not represent normal planti conditions. I would recommend setti trees 2 inches higher than they stood the nursery and constructing an earth cup of backfill mix to retain water duri watering operations.

Intensive inspection and strict enfor ment of contracts through the period guarantee are highly important. Lan scape designers, nurserymen, and inspe tors have spent time, effort, and mon in the selection of high-quality plan Planting plans have been modified as re quired to provide suitable conditions f planting stock. Individual trees shou consequently be planted, fertiliz watered, pruned, mulched, wrapped, a guyed as specified in the contract for t species and size of tree—if plantings a to be successful. Detailed specificatio for these practices vary considera among states, agencies, and municipa ties; but in one form or another t

practices considered desirable are specified for each planting project.

Considerable emphasis has rightly been placed in recent years on the need for a 3-year plant establishment period in every contract. Most arborists recognize this period of time as critical for plant survival. This 3-year period for establishment has not been adopted because of administrative problems. Unfortunately planting contracts still provide for only one growing season or a 12-month period, after planting, as the plant-establishment period. Most agencies consider any needed care or replacement, after this period, as maintenance. Problems include adequate definitions of plant replacement and care. Such items as watering, weeding, and application of insecticide are difficult to define adequately. Too often the terms "as required", "as directed", or "as needed" are used to define the frequency of treatment. Contractors therefore are guided by past experience with the particular agency, and they bid and perform accordingly. However, contracts providing separate items of plant care, such as watering, can result in increased plant survival. Contracts should, of course, require that all watering within a project be completed within a specified period of time.

### Maintenance

Maintenance of trees has always had low priority in the work programs of most administrators of highway programs. Consequently, budgets for tree maintenance are always inadequate.

Only when an epidemic that causes public concern develops, can adequate funds for tree maintenance be obtained. Extensive damage by gypsy moth in northeastern Pennsylvania has created such concern and provided support for a protective program. However, some other insect infestations, particularly in low populations, have not created sufficient public concern for protective action.

To provide adequate maintenance, after the acceptance of planting projects, many state highway departments are adopting a Highway Maintenance Management System (HMMS). It includes (1) development of standards for performance and frequency, (2) planning and programming, and (3) reporting for comparing performance with production goals. Such a system is invaluable in the preparation of budgets and work programs and in the analysis of operation accomplishments or deficiencies.

Tree maintenance can be performed successfully either by agency personnel or under contract by plant-maintenance services. Most rural districts and their employees are quite familiar with agricultural activities, and as a rule their personnel are used in plant-maintenance programs. Plantings in urban and suburban areas are best maintained through contract services. The increasing benefits demanded and gained by municipal unions make fiscally prudent the use of contract personnel who can be secured, as required, for short periods of time and then released. Through the use of contract personnel, overhead expenses such as social security, unemployment benefits, life and medical insurance, and retirement programs are not a continuing drain on the limited funds for tree maintenance.

Lack of widespread public support for maintenance programs is one good reason why landscape designers should incorporate into the design and in planting contracts species, planting, and establishment techniques that assure maximum survival despite inadequate maintenance.

Watering and insect control are the two most important items in most maintenance programs. Watering is the more important. "On-call" watering equipment is an important requirement, but difficult to obtain when needed. Severe summer droughts of the 1960s were a test of many organizations to conduct successful programs of tree establishment and maintenance. Then many apparently successful plantings were riddled with dying trees. Consequently species such as oak, linden,

and honeylocust gained prominence as desirable roadside trees because of their high survival.

Mowing can cause high mortality of planted trees because most operators seem to want to mow as close to tree trunks as possible. This often creates wounds for the entrance of disease or insects and sometimes directly kills trees. Many agencies have reduced the amounts of mowing through a mow-line policy, partly to save money and partly to encourage natural reproduction of woody plants.

However, reduced mowing may lead to damage by meadow mice in patches of dense unmowed cover. Many thin-bark trees are completely girdled during the winter and soon die. Such damage is particularly common in rural interchanges. Where trees are to be established in unmown areas, species should be carefully considered. Crabapples, hawthorns, and thin-bark maples are choice foods and poor risks. Large trees with thick bark, such as red oak and white ash in the 2½- to 3-inch caliper size (diameter 6 inches above ground) have had relatively good survival in such areas. Annual use of rodenticide around such trees is hazardous to domestic animals and also expensive.

Maintaining an area clear of vegetation around individual trees seems to be the most effective method of controlling rodent damage. While herbicide spraying or treatment has been effective in destroying undesirable vegetation, many plantings have been destroyed by improper use. A single misapplication can destroy desirable plants, and the expense and effort of many years are lost. This can also result in justifiable public criticism. Proper herbicide application is a must.

### Screening of Objectionable Views

State transportation departments use plant materials to screen visually offensive views—including their own storage yards. The Federal Highway Beautification Act of 1965 provided for the contro of outdoor advertising devices and junk yards along all interstate and primary highways receiving federal aid. Unde this act, billboards are to be purchase and removed except those in specificall permitted areas, and junkyards are to b removed or screened so the junk is no visible.

In using trees as screens, certain spe cies or types have definite advantages Evergreen plantings provide the mos effective year-round screens. Aroun highway-storage yards, soil may be con taminated with salt; so successful estab lishment of a screen may necessitat establishing it on an uncontaminate mound of soil. Fast-growing but long lived trees are the most desirable plant to use in screening junkyards. Howeve the species selected must be able t thrive under the pollutants from th nearby highway *and* from junkyard ope ations. In such situations narrow-growin plants may also be required to fit th available space.

Tree screens may be damaged or de stroyed because they are effective. Tre within highway rights-of-way have bee purposely cut, trimmed, sprayed, o otherwise destroyed to make visible a jacent billboards or business signs. I some states legislation is needed to pr vide better control of such damage. S vere penalties should be applied apprehended individuals, and in ma states they are.

## POSSIBLE USE OF CULTIVARS ALONG HIGHWAYS

In a recent survey by Gerhold *et a (1975)* under the Pinchot Institute pr gram of the U.S. Forest Service, muni palities, counties, and state highw departments were contacted. The som what incomplete reports showed th 754,567 trees were planted by muni palities and highway departments of northeastern states between 1968 a 1972. Highway departments plant

473,255 of these trees, or about 100,000 a year. Even a 10-percent evaluation of these trees, or about 10,000 a year, would provide much data on the relative value of different species and cultivars and would indicate needed research in tree improvement.

The Ohio Agricultural Research and Development Center at Wooster has conducted an evaluation program since 1966. As a result, Kozel *(1975)* identified 23 species and 63 cultivars that in his opinion possess sufficiently favorable qualities to justify their extensive use as street or park trees. However, more extensive evaluation programs covering the Northeast are needed to provide landscape designers and others with a sound basis for selecting specific trees for planting along highways.

I suggest that, through coordinated federal and state programs, incentives for planting and evaluating cultivars be developed. Possibly the Federal Highway Administration (FHWA) might encourage the use of a specific percentage of the project or program funds for this purpose—as it has for certain other favored projects. I also suggest that a prudent limit be set on the initial tests of cultivars offering promise. If, for example, a maximum of 10 percent were permitted, the amount of stock evaluated under demanding field conditions would be large enough to stimulate propagators and nurseries alike to increasing their activities.

Selections should provide, after adequate testing, a gamut of trees to meet varied conditions. Especially valuable would be species or cultivars that possess tolerance to poor drainage or to planting depth—factors that would increase their survival over most plants. Such selections would greatly aid all arborists—including those of us concerned with roadside plantings.

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# SELECTION PRACTICES OF MUNICIPAL ARBORISTS

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*ABSTRACT.* Selection of species or cultivars for municipal plantings involves complex social-political, managerial, architectural, biological, and commercial relationships. Various kinds of selection strategies may exist. A survey of arborists in the northeastern United States indicated that at least 17 characteristics of trees are considered in selecting species or clones for particular planting sites. The relative utility and availability of each type of information is compared. Personal experience was the main basis for selection, supplemented by various kinds of publications and nursery catalogs. Better information is needed—particularly about transplantability, maintenance problems, and resistance to air pollutants and deicing salts. Partial information is available on growth rate, general health, cold and drought tolerance, and disease and insect resistance. Ways to improve the selection of species and cultivars are suggested.

IN SELECTING TREES for planting, a municipal arborist may choose among hundreds of species and cultivars, each with its unique set of perhaps 20 characteristics. How can he cope with such a vast array of data? What would be the ideal way of finding the best tree for a particular site? How is the choice made, in actual practice?

An arborist's professional reputation depends to a great extent on his ability to recommend the best trees for various kinds of planting sites. Serious problems can result from faulty choices, and too often they do. Poor survival, sickly trees, maintenance problems, or excessive size may lead to strained budgets, complaints from taxpayers, or worse consequences. In contrast, wise selections bring amenities that may be enjoyed for generations.

Nurserymen who grow the trees and breeders who are developing superior cultivars also have a lot at stake in this matter. Their selection strategies are

directly related to those of the arborists *(Collins 1971, Santamour 1968)*. It is important for all three to understand the actual ways by which trees are chosen and purchased, and also to consider how the process might be improved.

The interpretive part of this report attempts to clear away some of the mysteries surrounding the planting choices that have beautified some communities and horrified others. The factual portion is based mainly on a survey of arborists and on related literature. A composite description is given of current practices of experienced arborists, and of the kinds of information they either use or wish they had available for use.

## CONTEXTS OF THE SELECTION PROCESS

Several kinds of forces may influence the planting choices made by a municipal arborist or a street-tree commission. If such pressures are managed wisely, rational selections can be expected. But there are many pitfalls along the way. For a fuller understanding of the selection process, one should consider the contexts in which it occurs.

### Social-Political Context

The underlying reason why trees are being chosen is that the residents of a community want them. The interested parties include nearby property owners, other taxpayers, and their public servants. In different communities or states there are various legal arrangements for such legitimate interests to be represented. The predominant role in making decisions may be assigned to a municipal arborist, a shade-tree commission, or property owners *(Boers and Shaw 1971)*. Most citizens seem content to leave tree selection to someone else, unless their active participation is encouraged in some way. Quite commonly the number of people who make the choices is very small, even as few as one. Therefore, it is quite possible for decisions to be autocratic, or else vulnerable to the persuasion of experts or crackpots.

### Managerial Context

Money and other resources needed for tree work always seem to be scarce. Budgetary pressures favor the purchase of cheaper species or cultivars. But wise shoppers realize that quality should be considered along with price. Some of the more expensive trees may turn out to be real bargains if they have longer useful lives or require lower expenditures for pruning, spraying, or sidewalk repairs. Stanley and Crossman *(1973)* developed a method of economic analysis for street trees and reported different costs according to size classes. Kielbaso *(1971)* reported that an average expenditure for maintenance of each street tree was $2.47 per year. In a 50-year period this would amount to over $120, or over $500 at 5 percent interest. A $5 difference in purchase price could buy considerable savings, if invested wisely.

### Architectural Context

Spatial relationships are very important in choosing trees that will be appropriate for aesthetic and functional purposes. These may include visual and psychological effects, pedestrian-traffic control, glare reduction, microclimate modification, acoustical control, and atmospheric purification *(Robinette 1972)*. Trees should complement their surroundings not only when they are young, but also after they have grown to their full height and spread. Size, form, texture, and color of trunk, branches, foliage, flowers, and fruit should receive attention. Possible interference with overhead wires, lighting, sidewalks, underground utilities, or the vision of drivers and pedestrians may be even more important. Many of the improved cultivars have been developed with such consideration in mind *(Kozel 1975, Wyman 1969)*. They should be used much more effectively than they have been previously.

### Biological Context

The ability of trees to survive and remain healthy for many years after planting is paramount among all characteristics under consideration. Trees that cannot meet this criterion are practically useless. Environmental relationships of many kinds should be evaluated in selecting trees that are reasonably well adapted to city conditions *(Collins 1972, Flemer 1972a and 1972b, Mower 1974, Santamour 1968 and 1969, Seibert 1972, Snyder 1972, Spicer 1971)*. Reactions of trees to stresses caused by cold, heat, wind, drought, ice, toxic chemicals in air or soil, restricted root space, diseases, insects, and vandals are all important. The relative importance of each is greatly influenced by geographic location and also by type of planting site; for example, business district versus residential street. Environmental stresses generally have greater effects on those characteristics that are under weaker genetic control than on others. Differences in reactions tend to be greater among species, but considerable variation also exists within species.

It is the municipal arborist's responsibility to determine from all these kinds of biological information which species could be grown under particular conditions. He also must decide which of these species or cultivars are architecturally most desirable, and acceptable in the social-political context. If he can find his way through this complex maze without serious damage to his integrity and principles, it may be only slightly less than miraculous. But he still faces one more hurdle.

### Commercial Context

The chosen tree must be found in the appropriate size at a nursery that can supply it at the right time, in good condition, and at a reasonable cost. This would present no great difficulty, if the arborist could place his order 10, 5, or even 2 years before the delivery date. Unfortunately, that seldom is feasible. So the nurserymen can only second-guess his customers of various types; and also his competitors, the weather, the economy, and labor conditions—to mention just a few of his problems. Then the arborist must make do with what is available when he is ready to place his order. If bids are required by his agency, the arborist will have even less control and is more likely to get inferior trees.

## KINDS OF SELECTION STRATEGIES

In view of these manifold and difficult problems, it is not surprising to realize that arborists have developed different strategies for dealing with them. There are various indications that different strategies exist, but little definitive information about them *(Bradley 1969, Collins 1972, Scanlon 1965, Spicer 1971, Walter 1969)*. For this reason, much greater liberties are taken with the truth in this section than are to be expected in a scientific discourse. Our observations admittedly are based on hearsay and inferences, more than on solid facts.

"GAMES ARBORISTS PLAY" could serve as a subtitle. Games are described that are analogous to possible selection strategies. Some are played only by pseudo-arborists, but not by professional experts. The tongue-in-cheek descriptions are intended to have only some resemblance to reality. See if you can recognize the games, or anyone you know among the players.

### "Blind Man's Bluff"

With blindfold in place, a player called the "Arborist" goes around in circles, searching for other players representing "Tree Species". Confounded by voices all around him, he turns hither and yon until he blunders into the most accessible species. He is required to explain his choice of species, and that's when "The Bluff" occurs. With a little imagination, some really wild, barely plausible excuses can be conjured up. When "The Bluff" fails,

which happens often, another player replaces the "Arborist".

If there are lots of players, several blindfolded "Arborists" may play at the same time, giving each other advice freely. This version is named "The Blind Leading The Blind".

### "Architectural Classics"

A sophisticated puzzle that challenges your three-dimensional perceptual acuity. Multicolored pieces in geometric shapes resembling trees, streets, buildings, and utilities fit together in the most ingenious ways. After the puzzle has been assembled, alas, some of the tree pieces are apt to fall apart. Others expand excessively, because the biological material from which they are made tends to have dimensional instability. The manufacturer is attempting to correct these vexing defects.

### "Don't Fool Around with Mother Nature"

A party game, not for beginning arborists, and not as seductive as it may sound. The format is similar to "Charades". The trick is to separate the facts from the myths about trees, so that the best solution can be recognized. The lead player, "Mother Nature", is full of tricks, and her clues often are ambiguous. Sometimes there are surprise endings. It takes real mental giants to play this one. Too often the trees turn out to be the giants, and the players, mental midgets.

### "Arborists' Monopoly"

Consummate skill and experience are required to be successful in the arborists' version of "Monopoly". In this game investments are made in trees, instead of real estate. At the start, each arborist has ample funds, which are generously supplemented by $200 when he passes "Go" at budget time. Occasionally he has an opportunity to take a "Chance", with either hilarious or tragic consequences. As he gains in skill, he finds that wise investments improve his financial status, but a certain amount of luck is needed, too. Although risks must be taken, a spirit of reckless abandon can lead to bankruptcy. Sooner or later, most players learn that nearly every move early in the game involves an opportunity to make a good or bad decision, and that they must face the consequences later on. Some players cannot stand the strain, and are relieved when they are instructed, "Go Directly to Jail".

These games are, of course, full of fallacies which are to be avoided. Choosing the proper tree should not be taken lightly. Nevertheless, selection does require skill and strategy, and it can bring enjoyment, just as in games. Our challenge is to invent a better way of playing the game. The key to improving this decision-making process is to obtain more extensive and reliable information and to develop better strategies for using pertinent information.

## INFORMATION USED IN SELECTION SYSTEMS

Arborists have accumulated a wealth of practical experience related to selection. Much of this has not been reduced to a written form. In an attempt to tap this information, a survey of 93 municipal and highway arborists in 13 northeastern states was conducted in 1974. Its purpose was to learn about the types of information arborists use, in order to improve the process by which species and cultivars are selected for planting. The same questionnaire used for this purpose also asked for opinions on suitability of the more important species for various types of planting sites, and on their characteristics.

### Information Types and Sources

Planting-site characteristics and tree characteristics are the two main kinds of information to be considered. Some site characteristics are used more commonly than others (table 1). Growing-space restrictions, both above and below ground, greatly limit the choices in many situations *(Boers and Shaw 1971)*. Prox-

Table 1.—Site characteristics used in selecting species for planting

| Characteristics | Used by respondents |
|---|---|
| | *Percent* |
| Growing-space restrictions | 97 |
| Distance to paved areas | 94 |
| Soil characteristics | 69 |
| Pest occurrence in locality | 52 |
| Distance to pollution sources | 47 |
| Microclimate | 31 |

imity to other trees, streets, sidewalks, buildings, and utility lines all affect the size and shape of crowns and root systems for which there is space. Nearly all arborists in the survey take account of space restrictions. Soil data, used by 69 percent, presumably may include texture, acidity, nutrients, moisture conditions, or aeration. The risk of disease, insect, or pollutant injuries is utilized by about half of the arborists, while only 31 percent are concerned about the microclimate. These types of data are obtained from inspections of planting sites, or are retrieved later from records kept in the office (table 2). The functions that trees are intended to serve can conveniently be considered when the planting site is inspected. In some municipalities the data are transformed into a master planting plan.

Having surveyed the planting site, the arborist then must decide which kind of tree is best suited to grow there and serve its intended purpose. His personal judgment, experience, and retention of facts take on greater importance than published information at this point. Personal experience was the most important source of information for arborists in the survey (table 3). The experience and preferences of others also were influential. Data in government publications, nursery catalogues, professional publications such as *Arborists News* (now *Journal of Arboriculture*) and *American Nurseryman,* or scientific journals such as *Forest Science* or *HortScience* are commonly used too.

There are at least 17 important tree characteristics that may be considered (table 4). Arborists indicated that nearly every characteristic that we listed is useful. Our survey results are in good agreement with a nationwide survey *(Bassett and Lawrence 1975),* which found that diseases, insects, and maintenance are the three most pressing problems. Other traits such as transplantability, soil requirements, and shade tolerance may be important too, but they were not included specifically.

The relative need for additional or better information on certain traits is indicated by the difference between their utility and their availability (table 4). The greatest needs pertain to air-pollution resistance, survival records,

Table 2.—Types of records kept by municipal and highway tree planters

| Type of record | Kept by respondents |
|---|---|
| | *Percent* |
| Planting location | 91 |
| Planting-site characteristics | 21 |
| Species | 83 |
| Cultivar, clone | 44 |
| Number of trees | 77 |
| Size of trees | 76 |
| Survival after 1 year | 47 |
| Survival after 2 years | 33 |
| Survival beyond 2 years | 29 |
| Causes of mortality | 32 |
| Pest occurrence | 30 |
| Cultural treatments | 20 |
| Maintenance operations | 63 |

Table 3.—Value of different information sources in selecting species for planting

| Source | Mean value[a] |
|---|---|
| Personal experience | 2.7 |
| Experience and preference of others | 2.3 |
| Nursery catalogs | 2.2 |
| Professional publications[b] | 2.2 |
| Scientific journals[c] | 1.6 |
| Government publications | 2.4 |
| Other | 1.4 |

[a] Scale: 1 = not important to 3 = very important.
[b] Mentioned most: Arborists News; Int. Shade Tree Conf. Proc., Am. Nurseryman.
[c] Mentioned most: HortScience; For. Sci.

Table 4.—Tree characteristics that are useful for selection

[In percent of respondents]

| Type of information | Respondents said information— | | Index of need[a] |
|---|---|---|---|
| | —is useful | —is available | |
| Air-pollutant resistance | 87 | 20 | 67 |
| Records of survival elsewhere | 90 | 28 | 62 |
| Deicing salt tolerance | 87 | 25 | 62 |
| Maintenance problems | 95 | 41 | 54 |
| Drought tolerance | 87 | 37 | 50 |
| General health | 85 | 46 | 39 |
| Insect resistance | 93 | 54 | 39 |
| Growth rate | 89 | 53 | 36 |
| Disease resistance | 96 | 60 | 36 |
| Cold tolerance | 80 | 48 | 32 |
| Availability from nurseries | 91 | 62 | 29 |
| Adaptive traits of rootstocks | 38 | 11 | 27 |
| Branching habit | 85 | 73 | 12 |
| Crown size | 87 | 81 | 6 |
| Crown shape | 86 | 85 | 1 |
| Fruit traits | 79 | 81 | −2 |
| Flower traits | 79 | 82 | −3 |
| Leaf traits | 76 | 80 | −4 |

[a] Index of need = Useful minus Available.

deicing-salt tolerance, maintenance problems, and drought tolerance. Somewhat better but still inadequate information exists on general health, insect resistance, growth rate, disease resistance, cold tolerance, availability from nurseries, and rootstock adaptiveness. Adequate information is available on traits related to appearance and size.

### Information Applications

The way in which information on each tree characteristic is used varies according to the biological, architectural, and managerial contexts in which it is considered. It also differs if the choice is being made among species, as compared to cultivars of a single species (table 5). Most commercial cultivars are clones budded on seedling rootstock. Arborists are more discriminating in choosing among species than cultivars within species. Also, greater attention is paid to appearance and dimensions of cultivars than their adaptiveness to environmental conditions. These tendencies probably reflect the greater amount of variation among species, the traits for which most cultivars were selected, and the availability of better information to guide choices in these two respects.

In assessing the importance of a particular characteristic, one should remem-

Table 5.—Use of genetic variation in tree characteristics for selecting species or cultivars

| Characteristics | Percent of respondents who utilize variation among— | |
|---|---|---|
| | Some or all species | Cultivars in some or all species |
| Crown size | 95 | 75 |
| Crown shape | 94 | 76 |
| Leaf size or color | 88 | 67 |
| Flower coloring or timing | 80 | 63 |
| Fruit size, color, etc. | 83 | 65 |
| Branching habit | 97 | 79 |
| Rooting habit | 95 | 62 |
| Trunk straightness or color | 92 | 71 |
| Cold tolerance | 90 | 61 |
| Drought tolerance | 91 | 61 |
| Salt tolerance | 85 | 58 |
| Air-pollution resistance | 73 | 49 |
| Insect resistance | 94 | 65 |
| Disease resistance | 98 | 68 |

ber that it is not independent of the other traits associated with it in a species or cultivar. The characteristics in which a species is weakest are the ones most likely to lead to its rejection by an arborist. These are also the traits that breeders should consider improving, though not necessarily those that will respond best to improvement efforts.

## IMPROVING SELECTION SYSTEMS

Let us return to a question raised earlier. How can arborists cope with such a mass of data, interpreting it in various contexts, and do a better job of it? The tempting answer is to refer it to a computer. This may become possible, if adequate programs are written and better data are obtained. The process could at least be simplified, though we believe an arborist's judgment will still be required in making final decisions.

A more immediate improvement might be realized by using the collective wisdom of experienced arborists and organizing data so they can be utilized more effectively—despite their imperfections and inaccuracies. Therefore we have started to compile a table that summarizes the reputations of the more commonly planted species and cultivars in terms of size and appearance, maintenance characteristics, and performance under various kinds of site conditions. The information is based on several publications of experts *(Chapin and Kozel 1975, Enright 1955, Flemer 1972a, Kozel 1974 and 1975, Lewis 1965 and 1971, N.J. Fed. Shade Tree Comm. 1974, Scanlon 1965, Snyder 1972, Wyman 1965 and 1969)* and on the survey of arborists which we conducted.

The tabulated information may be used in various ways. Experienced arborists may use it as a check list, or to compare their opinions with those of others. Beginning arborists or novices can use the summary of conventional knowledge to supplement what they have learned from books, as a temporary substitute for professional experience. Tree breeders and researchers can identify species and characteristics in which genetic improvements would be useful or for which information is lacking.

The arrangement of data on species and cultivars should enable the user to employ his own strategy for sorting out the trees he wants. They should be listed without subdivision into categories such as size or hardiness zone. This will free the user to design his own search procedure. He can decide on the sequence in which different kinds of data will be considered, according to the meaning they hold for him. The most appropriate candidates for a particular use can be located by considering different variables in succession. The final choice can be made through a blending of science, art, and experience, which can be unique for each user.

A final word of caution is needed about imperfections in the data that are available. The performance of trees under city conditions varies greatly. Such variations have been noted subjectively, but objective measurements are scarce. There is a great need for more scientific data to develop improved selection guides. Arborists in our survey have clearly recognized this need. Many of them are already engaged in cooperative projects that aim to provide the information that will permit arborists and breeders to select more effectively.

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# NURSERY GROWING PRACTICES AS RELATED TO SELECTION AND PRODUCTION OF MUNICIPAL TREES

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*ABSTRACT.* The commercial production and selection of trees for municipal plantings are traced from the early phase to the current propagation and cultural techniques that commercial nurseries are now using. Street-tree production is a long cycle, usually 3 to 5 years from the time 5- to 7-foot seedlings (liners) are spaced and planted in nursery rows. Clones provide municipal buyers with trees of known desirable characteristics and without the undesirable variability of seedlings. However, 6 to 15 years are needed to evaluate a clone, and many promising selections fail to meet acceptable standards for various reasons. Improved means of vegetative reproduction, especially "own-root" propagation, are sadly needed to permit the more efficient production of desirable clones of various species.

VOLUME PRODUCTION OF TREES for municipal planting is a specialized phase of the nursery business. The kinds suitable for street-tree planting are limited. Their production involves some specific cultural practices that begin with propagation techniques and end with refinements in digging and storage methods.

As would be expected in a free-enterprise business, no two firms of wholesale growers use the same production methods, grow the same kinds, or supply the same markets. However, most of them have at least two things in common: (1) their procedures in growing, grading, and selling are geared to meeting or exceeding industry standards (American Association of Nurserymen 1973); and (2) the nurseries strive to annually supply municipal and other buyers with the numbers, kinds, and sizes of stock required.

Many of us recall that the trees formerly grown by nurseries for all of their trade, including the municipal market, were of seedling origin. Then production practices were largely confined to selection of seed source, spacing of stock, its training and shaping, the frequency of transplanting, and digging and storage methods. As professionally trained arborists and foresters gained the responsibility of personnel and budgets, the planting programs of their predecessors showed some failings: municipal trees too large at maturity for the site, a lack of variety in species, and poor tree structure

resulting from inadequate training and shaping.

Interested growers and municipal planters gradually learned that both groups would benefit by exchange of information. Then began what continues to be a mutually advantageous arrangement: the nurseryman's personal observations of tree growth on city streets and highways, and municipal arborists' visits to nurseries, sometimes on field days, to see improved modifications in nursery practices. Goal of the interchange is, of course, to provide proper kinds, sizes, and shapes of trees for municipal plantings.

Both groups have one hurdle or barrier in common, the economic one. For the nurseryman, the price per tree is set largely by the cost of production. For the city arborist, landscape architect, or other buyer, the budget limits the number of trees meeting certain specifications that can be purchased. As a nurseryman, I welcome the opportunity to discuss some of the procedures and problems that contribute to the cost of producing this specialized nursery stock.

## STREET-TREE PRODUCTION—A LONG CYCLE

Annually the nurseryman sets up a new production cycle to supply the needs of the specialized municipal market at a competitive price. He develops a schedule of individual timetables that cover the full line of trees and that indicate by year of harvest the quantities and sizes he will have available. Each cultural step is planned, so that as the trees in each block reach salable size, they are properly formed, pruned, and spaced. If the nurseryman has to dig the trees in one block a year sooner than scheduled, most of them will be "unsized"—smaller in height or diameter than called for in the minimum specifications. On the other hand, if the nurseryman has to allow the trees in a block to grow a year longer than planned, spacing both within and between rows will be undesirably close, trees may reach a larger than acceptable size, and production costs for that year have to be added to the selling price.

The production cycle varies with the growth rate of different kinds of trees

Table 1.—Average number of years required to produce street-tree stock from seedlings 5 to 7 feet tall or from 1-year-old whips of that size, by species or clone[1]

| Species or clone | Type[2] | Years | Species or clone | Type[2] | Years |
|---|---|---|---|---|---|
| *Acer campestre* | S | 3 | *Fraxinus excelsior* | C | 3 |
| *Acer platanoides* | C | 3 | *Ginkgo biloba* | S | 4-5 |
| *Acer rubrum* | C | 3 | | C | 4-5 |
| *Acer saccharinum* | S | 3 | *Gleditsia triacanthos inermis* | C | 3 |
| | C | 3 | *Liquidambar styraciflua* | S | 4 |
| *Acer saccharum* | S | 4 | *Malus* 'Snowdrift' | C | 3 |
| | C | 3 | *Ostrya virginiana* | S | 4-5 |
| *Celtis occidentalis* | S | 3-4 | *Platanus acerifolia* | C | 2-3 |
| *Cercidiphyllum japonicum* | S | 4-5 | *Pyrus calleryana* | C | 3 |
| *Crataegus lavallei* (tree form) | C | 3-4 | *Quercus rubra (Q. borealis)* | S | 4 |
| *Crataegus phaenopyrum* (tree form) | C | 3-4 | *Quercus palustris* | S | 4 |
| *Fraxinus americana* | C | 3 | | C | 4 |
| *Fraxinus pennsylvanica lanceolata* | C | 3 | *Zelkova serrata* | C | 3 |

[1] To minimize variables in the above comparison, the years listed are the average number required to grow street-tree types to a caliper of 1¼ to 1¾ inches from liners or whips that are 5 to 7 feet tall. To these years add the average number of years required to grow liners (seedlings from seed) to the 5- to 7-foot size or to produce 1-year-old whips of that size that have 3-year-old roots.

[2] Type of stock produced: S = seedlings; C = clones.

(table 1). Only a series of the most favorable growing seasons permits the harvesting of even the fastest growing kinds in less than 3 years. These years do not include the time needed to grow seedlings to a height of 5 to 7 feet or to produce whips of budded varieties of the same height. These young trees, even though taller than usual, are commonly referred to as "liners" in the nursery trade. Planting of trees of this size permits the predictable harvesting of some street-tree types in sizes from 1¼ inch through 1¾-inch caliper in 3 years. Slower growing types may need 4 or 5 years to reach this minimal size range.

(A "whip" is an erect, usually straight and unbranched 1-year-old stem growing from a single bud, grafted [or more exactly, budded] the previous season at or near ground level on a suitable seedling understock. A "liner" [lining-out stock] includes all young plants of sizes suitable for planting in the nursery. In the case of street trees, the liners are sometimes relatively large trees. In recent years they are frequently 1-year whips of budded varieties up to 7 feet in height. They are "lined out" in the nursery, uniformly spaced to grow for two or more years before selling or transplanting again. Caliper is the diameter measured 6 inches above ground for trees up to and including 4 inches in diameter.)

Although some nurseries do engage in contract growing (in which the buyer agrees to take a specified number of trees of specific kinds and sizes in certain designated years), most sales to municipalities and other public agencies are by bids. Bid sales do not provide assurance to nurserymen that, as trees reach salable size, all of them will be sold on schedule.

Nurserymen cannot deviate from their production cycle, especially for trees grown to be sold as bare-root stock; and bare-root stock is the bulk of the governmental market. The buyer, like the nurseryman, has rising costs in labor, equipment, and supplies, but wishes for his budgeted dollars to purchase the maximum number of trees that meet specifications. Trees purchased as bare-root stock permit the buyer to plant more miles of street or to set out more replacements than if he buys stock with soil balls wrapped in burlap (B&B stock). Increasing use of bare-root stock seems likely in view of savings in cost and energy. Many more bare-root trees than B&B stock can be shipped in the same volume of space, and the resulting load weighs less and requires less use of fuel by the 40-foot truck vans that we use.

Should a municipal arborist find it necessary, he can obtain the maximum number of trees for his budgeted dollars if he modifies his preferred specifications so that he purchases:

1. A higher proportion of trees as bare-root stock.
2. Trees of a smaller, less costly size.
3. Species or cultivars that are less expensive than others of the same size.

Of course, the arborist has to judge whether the bare-root stock, smaller trees, or less costly species will give him and his community adequate survival and performance, and whether offsetting costs result.

## ENTER THE CLONE

Possibly the biggest single factor that has permitted the grower to meet the needs of the municipal buyer is the advent of the clone (cultivar). It has permitted the nurseryman and the forester or arborist, together or individually, to zero in on selections that grow well in street and highway plantings (fig. 1). These selections increase the cost of planted trees little, if at all, especially if the clone has acceptable growth and significantly superior performance when compared to the previously grown seedling trees. And clones do not have the variation found in seedling stock (fig. 2).

An extensive period of testing and evaluation has usually preceded the suc-



Figure 1.—'Snowdrift' flowering crabapple trees planted in sidewalk cut-outs. Note that the form of these trees is uniform and provides sufficient clearance for vehicular and pedestrian traffic.

cess of the best clonal selections, ones that meet the production standards of the nurseryman and the performance standards of the city forester. Important production factors that the grower must consider are ease of propagation with high survival rates, uniformity of growth, superior structural form, superior resistance to pest injuries, and pronounced vigor. The last includes an improved rate of annual growth, high percentage of survival in transplanting, and quicker recovery after transplanting. Clones having these characteristics will give the buyer uniformly excellent performance.

Poor performance of a clone need not be blamed on the tree. The cultivar may be planted north of the recommended hardiness zones. Some planting sites permit neither seedlings of the particular species nor their clones to survive, yet alone to thrive. Such sites and conditions can be classified in a *TOO SERIES*: too

Figure 2.—A block of 'Cleveland' Norway maples in the nursery, ready for digging and street planting. Note their uniform appearance, typical of clones. This is one of several fine cultivars for street-tree planting having an upright habit but form typical of the species.



poorly drained, too wet, too dry, too hot, too windy, too polluted (air, soil, or both), too small in soil-surface area or soil volume, too shady, too poor in quality of backfill, too little in maintenance care. Selection of clones and species for good performance on specific sites is a subject on which experienced and knowledgeable growers and arborists can exchange information to their mutual advantage.

The subject of this portion of the symposium is "selection for adaption to cultural systems," a concise way of suggesting that—if the grower cannot offer a selection at a price profitable to him and acceptable to the buyer—then the selection will not be commercially available on a sustained basis. I believe there are many fine species and a goodly number of individually superior specimen trees that will never be propagated to reach the market in volume—just because growers believe the costs of production exceed prices that government agencies can pay.

However, 50 to 100 years hence, 1975 may be considered the threshold of discovering, developing, and utilizing the genetic potential in the trees around us. As we pinpoint needs, so can we pinpoint our efforts. Early prejudices and categories that placed trees in lists are now being gradually removed or discarded. Many untested species are now being considered for potential use as municipal shade trees.

## ASPECTS OF SELECTION AND EVALUATION

### General Aspects

In the past there was little motivation for a nurseryman's involvement in the selection, evaluation, propagation, and testing of ornamental and shade trees. The change came when a need developed in metropolitan areas for kinds of trees that thrive and grow well in inner-city and highway plantings. This need gave us the opportunity to select clones for specific uses and effects: environmental tolerance, durable and predictable fall color, unusual floral effect, multi-season beauty (because of flowers, foliage, and fruit), distinctive functional form—to name a few.

A program for selecting, evaluating, and propagating tree cultivars is costly and time-consuming. It is best undertaken by a large wholesale-grower firm that produces a full lines of trees and has other markets in addition to the very important government market.

Whether a new selection originates from in-house efforts or from an outside source, reputable growers attempt to determine that this selection is, in fact, superior to the presently available kinds, or that it is sufficiently different, unusual, or unique so a potential market might exist. Without going into detail, I'll state that selections from different genera and species do require varying numbers of years in the testing program before comparable appraisals can be made. Appraisals of a flowering crabapple, a willow, or a poplar can be made after fewer years of observation than are needed for an oak or a ginkgo.

Substantial evaluation of certain growth characteristics or some other aspects will have to be made. These include:

1. What is the most economical method of propagation that produces a high percentage of trees having the desired size and form in the shortest time?
2. Will the existing cultural systems, which the nursery firm has determined are best suited to its overall operation, provide suitable methods of propagation and culture for the new selection?
3. Will the selection fit in the line of stocks that the firm is currently growing—in this case largely for the government market?
4. If sales of the selection are stimulated by reasonable advertising and promotion programs, will they soon reach and maintain a needed minimum?

(Cole Nursery's minimum is 500 per year.)

5. Is the quality of the selection up to the firm's previous introductions?
6. Is the selection patentable if the firm decides to apply? Patenting a plant does not guarantee market acceptance, but it does indicate the firm's belief in a strong and sustained demand for the new tree.

### Methods of Testing and Evaluation

There are many different successful programs in plant testing. The diversity is due to the fact that each business or agency has to tailor its program to fit its personnel, funding, land, and propagation facilities.

There are a few truisms I should mention:

- Extensive knowledge of a wide variety of woody plants is helpful.
- Familiarity with growth habits and environmental adaptabilities of the species and genera in the program helps in suggesting possibilities and in reducing poor leads.
- One can never know too much about propagation.
- Except for the hobbyist or plant specialist, the goal is market acceptability. Successful introductions of the past are paying for today's testing costs. Today's selections should pay tomorrow's bills.

### Cole's Evaluation Procedure

For each tree brought into Cole's program, a Test Plant Sheet (fig. 3) is filled out and placed in a loose-leaf binder, and it becomes the permanent record of the selection. Color slides of the selection are placed in transparent slide-holders and kept in the notebook with the test sheet. All notes, clippings, and back-up information that relate to the selection are kept in a separate file folder. For selections presently under consideration but not yet brought into the program, information is accumulated until the item is either acquisitioned or dropped. The last statement frequently applies to specimen trees growing outside the nursery; and for these, additional years of observation may be needed before a decision can be reached.

At the first opportunity, initial propagation work is started—with the goal of one or two dozen progeny of the parent tree. If the selection is in the nursery, propagation insures against possible loss when the parent tree is moved to a test-plant area. If the selection is growing outside, permission is obtained to collect propagation material.

A delay can be costly. We have lost the opportunity to test several promising specimens because site clearance, road widening, or accidental injury resulted in their removal before propagating wood was secured.

We want to know at the earliest possible date the selection's normal growth rate, its flowering and fruiting habits, and the natural shape it will assume. Pruning is, therefore, minimal on trees selected in the nursery. It is also minimal on one or two of the first propagated progeny for a selection growing outside of the nursery.

Nothing is as valuable as a color-slide record in evaluating tree selections. Photographing is not started until the progeny have grown enough or matured enough to substantiate earlier judgments. To make color evaluations constant, we have used Kodachrome II film (now replaced by Kodachrome 25). It permits valid color comparisons between different selections in the same season and between trees of the same selection in different years. Decisions on the worthiness of a selection for introduction or patenting are usually made by a group of management, sales, and production personnel. The color slides, test-plant sheets, field observations, and in-depth discussions give them the necessary information.

Too early culling of competitive selections may be unwise, and the evaluation period may be lengthy. For example, from a group of competitive selections, the

Figure 3.—The form used by Cole Nursery Company, Inc., to record data concerning the selection and evaluation of individual clones.

TEST PLANT SHEET NO. _____Date initially filled out _____

PLANT NAME _____
*(botanical)* *(common)*

Acquisition Number _____Other Names, No's _____

## ANTICIPATED MARKET POTENTIAL

as rated, date _____ *(red)*; as rated, date _____ *(blue)*; as rated, date _____ *(green)*

REASONS PLANT SELECTED FOR TEST _____

**(Below, Circle Most Appropriate Rating)**

1. Hardiest rating (Zone 2, 3, 4, 5, 6, 7, 8)
2. General Adaptability (wide - average - minimal)
3. Ease of transplanting (easy - average - difficult)
4. Ease of culture (easy - average - difficult)
5. Growth rate (fast - average - slow)
6. Can sell (Either B&B - b.r.) (Mostly B&B - b.r.) (Only B&B - b.r.)
7. Item is presently (well known - fairly well known - little known)
8. Plant to compete with, or to replace _____
9. Anticipated duration of demand (Long - 10 yrs. or more, Average - 5-10 yrs., Short - 1-5 yrs.)
10. Plant considered a (Superior form of a standard item, Superior Form of a lesser known item, Novelty item)
11. Volume of sales anticipated in (Retail nurseries, Government Agencies, Landscape Contractors, Golf Courses, Cemeteries, Other - specify _____

## HISTORY

1. Source and/or date of original information_____
2. Plant suggested by _____
3. Location Parent Plant, or Seed Source _____
4. Parent Plant property of _____
5. Authority for testing. Letter Agreement _____Contract_____ Other (specify)_____
6. Pictures in file _____Existing pics suitable for cat._____for advertising_____
   Color_____Black & White_____
7. Plant Patentable _____
8. Remarks _____

## PROPAGATION (Fill in, or circle as required)

1. Parent plant purchased _____, or received_____, date_____PO No._____
2. Parent location (after purchase) _____
3. Propagation material forwarded by - PP, UPS, CAR, TRUCK. by_____ (name & address) _____ (date) _____, as HWC, SWC, SCIONS, SEED, GR. PLT.
4. Received, date_____. CONDITION: EX, GOOD, FAIR, POOR
5. Units received_____Propagated (date) _____
6. Initial propagation by SWC, HWC, GR., BUD, SEED
   a. Understock used _____
   b. Understock source _____
   c. PO No. _____DATE _____ SIZE OR AGE_____
   d. Understock: Date (Potted) (Planted) _____
      Date (Grafted) (Budded) _____
8. Location, 1st prop. plants _____
9. Transplanted to_____date _____
   Transplanted to_____date_____
10. Remarks_____

NOTE: *Record as above, each successive attempted propagation. (After initial propagation/s, see R and D Book and/or Stock Books for further propagation records.)*

## CONCLUSION

Having been tested and scored (see Evaluation Sheets) for _____years, the plant

1. Should be eliminated from further testing because_____

   Plants propagated to date should be disposed of as follows_____

or 2. Should be increased and introduced as a non-patented item because _____

or 3. Patent application should be started because _____

   Patent application started - Date_____ By_____
   Patent Attorney_____
   Patent File No. _____
   Patent granted - Date_____Patent No. _____
   Patent Assigned to _____Date_____
   If plant introduced by other than above, specify _____

   If plant owned by other (s), patent assignment obtained by _____
   Date_____from _____

REMARKS: _____

number is reduced to four. In the initial propagation, the first one propagates poorly and is dropped. Progeny of the other three selections are lined out for growth comparisons in the field under the usual cultural practices for that particular species. By the end of the second growing season, progeny of the third selection are only half as tall as those of the other two selections, so the third one is dropped. At the end of this field test, the available data are reviewed, and the second selection is favored because its pattern of growth is somewhat more uniform than the progeny of the fourth. Past experience suggests holding competitive selections fairly long in evaluations because of mishaps such as mixup in identity, overwintering loss in cold storage, accidental grubbing, and poor survivals after too-late transplanting.

### Commercial Propagation Test

The acid test for a selection that has scored high in the initial evaluation is propagating and growing it to salable size of a minimal commercial quantity. Here the selection is handled as if it were already added to the line; so it receives the same method of propagation, the same cultural practices (spacing, pruning, shaping, etc.), as other clones of the same species. If progeny of the selection do well in the mini-commercial propagation test, it is then considered for an addition to the line and for possible patenting.

### Marketability: "The Head Chopper"

In spite of how promising selections are judged at the time they are added to the test program, most are dropped somewhere along the way. Reasons for eliminating them include one or more of the following:

1. Unsuccessful propagation from a parent tree not growing in the nursery.
2. Tree extremely difficult to propagate.
3. Seedling understock of that particular species not available for budding or grafting when propagation wood of the parent tree is available.
4. Susceptibility to a pest that was not previously observed.
5. Reports from cooperators indicate hardiness less than anticipated.
6. Unacceptable degree of incompatibility with seedling understock.
7. Growth rate of the first-propagated progeny too slow to be commercially acceptable.

Because a large part of the municipal market prefers to buy bare-root trees, a slow-growing but otherwise superior clone would not be competitive if it had to be offered for sale only as B&B stock—trees in such form costing 2 to 3 times more than bare-root trees of the same size.

Marketability is "the head chopper". From the time the evaluation of a selection is started, the one burning question that is repeatedly asked is: "Will this item be marketable in substantial, sustained numbers?"

### Period of Evaluation

The period of evaluation is extremely variable. It is usually shorter for fast-growing trees than for slow-growing trees, for kinds that bloom and fruit early, for kinds that are easily propagated, as by budding, for kinds that are inherently pest-free, and for selections from species with which the firm has experienced a favorable record of production and marketing. For genera like *Malus* and *Crataegus* the period may be 6 to 8 years; for late-maturing genera like *Ginkgo* and *Quercus* 12 to 15 years; and for intermediate types 8 to 12 years.

However, there are other variables. If the parent tree is mature, the period may be shortened—because we can judge the probable shape of vegetatively reproduced progeny by it. However, if the parent selection is a relatively young seedling, the test period may have to be stretched out—especially if one of the main reasons for its selection is an assumed mature form.

## PROBLEMS IN VEGETATIVE PROPAGATION

### Graft Incompatibilities

Propagating vegetatively new clones of shade and ornamental trees provides opportunities in the volume production of species seldom reproduced other than by seed, but problems have developed in grafting (often budding, rather than use of a scion). Observed incompatibilities include:

1. A swelling or overgrowth near the point of union, usually on the graft just above the union.
2. Incomplete "knitting" of graft and understock so only a portion of the union appears normal. This may cause uneven increases in diameter at the point of union.
3. Partial incompatibilities that are relatively difficult to detect. One shows up as premature fall coloring on scattered trees in a nursery block, especially among red and silver maples. A check then usually shows poor or weak unions on affected trees, which are also usually somewhat smaller and less vigorous than unaffected trees. Affected trees are considered unsatisfactory and are grubbed out. Presumably some percentage of unaffected stems may also have an incompatibility that might show up later. For example, a small percentage of the 'Sovereign' pin oaks, originating from buds or grafts, have broken cleanly at the point of union under the stress of a severe wind or impact—even though the unions had nearly normal appearance.

   Another symptom of incompatibility is a more than normal amount of sprouting, often as basal suckers, of the understock below the union. This may be caused by a difference in vigor of the understock and of the graft; and it occurs most commonly in *Malus*, but also to varying degrees in *Pyrus* and *Crataegus*.

### "Own-Rooted" Trees

"Own-rooted" progeny should be a mirror image of the parent tree, but be free of the problems of incompatibilities found in grafting. "Own-rooted" progeny form the best alternative for clones susceptible to graft incompatibilities.

Propagation of "own-rooted" trees usually means by softwood or hardwood cuttings, but for certain selections propagation might be by root pieces. I have observed that when trees of certain kinds are dug for B&B stock with a tree spade, new plants may develop from root ends if the holes are not backfilled. Tree spades sever roots smoothly. Sprouting from the exposed root ends occurs quite readily in *Gleditsia*, *Liquidambar*, *Malus*, and *Prunus maritima*.

Problems in "own-root" propagation include at least the following:

1. A larger amount of scion material is required for the same number of progeny than in budding or grafting.
2. Growth during the first year, and sometimes into the second or third years, lags behind that of grafted trees.
3. Trees that have slower growth during the early years are likely to be less well-formed than rapidly growing stems from other methods of propagation.
4. Age of the propagated tree affects transplanting success and rate of recovery. Other factors being equal, the younger the tree, the more likely it will transplant successfully as bare-root stock.

However, advances in "own-root" propagations are, I believe, sadly needed. Can the techniques of this propagation method be so improved that it could become economically competitive with budding?

## CONCLUSION

In this paper I have pointed out the long cycle involved in shade-tree production and the even longer cycle involved in the selection and evaluation of shade trees. I stressed the need for improved methods of vegetative reproduction if clones that are difficult to propagate are to be selected, produced, and used. If a clone cannot be mass-produced at reasonable prices, even the most desirable one will receive limited, if any, acceptance in the trade. Hence the need for providing effective means of vegetative reproduction is often as important as the initial selection and evaluation of clones.

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# WINTER INJURY TO CONTAINER-GROWN PLANTS

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*ABSTRACT.* The overwinter survival of woody ornamental plants growing in containers or in raised planters depends on the cold-hardiness of the roots and on the amount of protection from the cold that the roots receive. Temperatures at which roots of many ornamental plants are killed range from −5°C to −18°C. The temperatures at which roots are killed depend partly on the age and maturity of roots: old roots are more cold-hardy than young roots. Increasing the cold-hardiness of roots through the use of growth regulators or fertilizers seems impractical at present.

CONTAINER PRODUCTION of ornamental plants allows nurserymen to grow a greater number of plants per acre without significantly increasing labor cost over that required for field production. Because the media are modified for optimum growth of plants, ornamentals grow more uniformly in containers than under field cultivation, and plants reach marketable size in minimum time. Furthermore, plants growing in containers can be transplanted successfully almost any time of the year.

Most ornamental plants are adaptable to container production. However, plant height and spread are limited by the size of the containers used. Large upright plants can be grown in containers, but stability is a serious problem.

One of the major factors limiting the use of containers by the nursery industry of the Northeast is root damage when ornamentals are overwintered in containers. Until recently, most winter injury has been attributed to desiccation. To prevent desiccation, nurserymen have constructed inexpensive plastic-covered greenhouses to protect their plants from drying winds, scorching sun, and rapidly fluctuating temperatures. To reduce heat buildup during warm winter days and in the early spring, the greenhouses are either covered with white plastic or painted with white latex paint. However, even in the protection of these greenhouses, many species of ornamentals seldom survive most winters without symptons of winter injury. Although the symptoms may go unnoticed until early summer.

The difference in winter-hardiness of plants growing in the ground and of the same species growing in containers or

planters has been a difficult-to-resolve problem. Winter injury is seldom a problem in these species when the plants grow in the nursery field or landscape. In recent years several studies have demonstrated that winter injury of many species of plants growing in containers can be attributed to lack of root hardiness *(Gouin 1969; Havis 1972, 1974; Havis and others 1972; Mityga and Lanphear 1971).*

## ROOT SUSCEPTIBILITY

It has been known that the roots of woody plants are not as cold-hardy as the above-ground portions. However, the differences in cold-hardiness between roots and stems or leaves have never been determined for ornamentals.

Because container-grown plants are grown above the surface of the ground, roots within the growing media are subjected to nearly the same low temperatures as the tops. Nurserymen and landscape contractors have generally overlooked this difference in cultural methods when selecting plants to be grown in containers.

In 1970 Havis published a list of 19 species of ornamentals and their root-killing temperatures. In 1974 he expanded this list to include 30 species (table 1). His list indicates great differences among species of ornamentals and the temperatures at which roots are killed.

Havis reported that different species may not show similar responses in stems and foliage to root injuries. Species of *Ilex, Daphne,* and *Cryptomeria* that had damaged roots maintained normal healthy foliage while under cool, moist conditions; but when they were ex-

Table 1.—Tolerance of plant roots in winter storage to low temperatures[1]

| Species or cultivar | Safe temperature | | Killing temperature | |
|---|---|---|---|---|
| | °F | °C | °F | °C |
| *Magnolia soulangiana* | 26 | (— 3) | 23 | (— 5) |
| *Magnolia stellata* | 26 | (— 3) | 23 | (— 5) |
| *Cornus florida* | 24 | (— 4) | 20 | (— 7) |
| *Daphne cneorum* | 24 | (— 4) | 20 | (— 7) |
| *Ilex crenata* 'Convexa' | 24 | (— 4) | 20 | (— 7) |
| *Ilex crenata* 'Hetzi' | 24 | (— 4) | 20 | (— 7) |
| *Ilex opaca* | 24 | (— 4) | 20 | (— 7) |
| *Ilex crenata* 'Stokes' | 24 | (— 4) | 20 | (— 7) |
| *Cotoneaster horizontalis* | 22 | (— 6) | 18 | (— 8) |
| *Pyracantha coccinea* | 22 | (— 6) | 18 | (— 8) |
| *Cryptomeria japonica* | 20 | (— 7) | 16 | (— 9) |
| *Cotoneaster adpressa praecox* | 20 | (— 7) | 16 | (— 9) |
| *Viburnum carlesii* | 20 | (— 7) | 15 | (— 9) |
| *Cytisus praecox* | 20 | (— 7) | 15 | (— 9) |
| *Acer palmatum* 'Atropurpureum' | 17 | (— 8) | 14 | (—10) |
| *Taxus* X *media* 'Nigra' | 15 | (— 9) | 10 | (—12) |
| Azalea 'Gibraltar' | 15 | (— 9) | 10 | (—12) |
| Azalea 'Hinodegiri' | 15 | (— 9) | 10 | (—12) |
| *Kalmia latifolia* | 15 | (— 9) | * | |
| *Leucothoe catesbaei* | 15 | (— 9) | * | |
| *Mahonia aquifolium* | 15 | (— 9) | * | |
| *Pieris floribunda* | 15 | (— 9) | * | |
| *Pieris japonica* | 15 | (— 9) | * | |
| *Rhododendron carolinianum* | 15 | (— 9) | * | |
| *Rhododendron catawbiense* | 15 | (— 9) | * | |
| *Thuja occidentalis* | 15 | (— 9) | * | |
| *Euonymus fortunei* 'Colorata' | 10 | (—12) | 5 | (—15) |
| *Juniperus horizontalis* 'Plumosa' | 10 | (—12) | 0 | (—18) |
| *Juniperus horizontalis* 'Douglasii' | 10 | (—12) | 0 | (—18) |
| Rhododendron 'PJM' | 10 | (—12) | 0 | (—18) |

[1] From Havis *(1974)* and published here with his permission.
* Killing temperature of roots has not been determined, but safe temperature has been estimated from storage experiments.

posed to warm, drying conditions, their leaves shriveled and died. *Cornus*, *Magnolia*, and *Viburnum* plants that had suffered root damage started to leaf out, or to develop new shoots, and then suddenly wilted and died. Root-damaged plants of *Cotoneaster* and *Pyracantha* looked normal for a few weeks, even in warm weather, and suddenly died just after new growth started. Root-damaged plants of *Taxus* and *Juniperus* remained apparently healthy but did not grow.

The age and maturity of roots affect their cold hardiness. Mityga and Lanphear *(1971)* found from their study of artificially hardened plants of *Taxus* X *media* 'Hatfieldii' that young roots (cream- to white-colored roots, including root tips) were killed at −3°C; secondary mature roots (dark red to brown roots immediately above young roots) were killed at −7°C; and primary mature roots (roots near the base of the stem) were killed at −11°C.

Winter-storage conditions can greatly modify root losses to cold temperatures. In a study of container-grown *Buxus sempervirens*, some plants were overwintered in an unheated plastic shelter, and other plants were protected by microfoam *(Gouin 1969, 1973)*. The latter plants, which had no visual injury to their root systems, produced more top growth during the following season than plants stored in the unheated plastic shelter, and they had dry and shriveled roots in the spring (fig. 1)—even though all plants had apparently healthy foliage. Similar treatments of *Ilex crenata* growing in containers also produced marked differences in the appearance of root systems in the spring. Roots of plants overwintered in the unheated plastic shelter looked black and water-soaked when the containers were removed from storage, whereas roots in the microfoam treatments were white and active (fig. 2) and similar in appearance to *Ilex* roots before winter storage.

## ROOT INJURY AS IT AFFECTS SURVIVAL AND GROWTH

Differing extent of damage within root systems seems to be responsible for great differences in the growth of tops among container plants of the same species. Plants that have suffered extensive root damage from being overwintered without adequate protection are less likely to grow during the following spring




Figure 1.—Buxus sempervirens plants at the end of the second growing season. Plant A was protected from cold injury to its root system during the previous winter by the use of microfoam. Plant B was overwintered in an unheated, plastic-covered shelter; and its roots were damaged by cold.

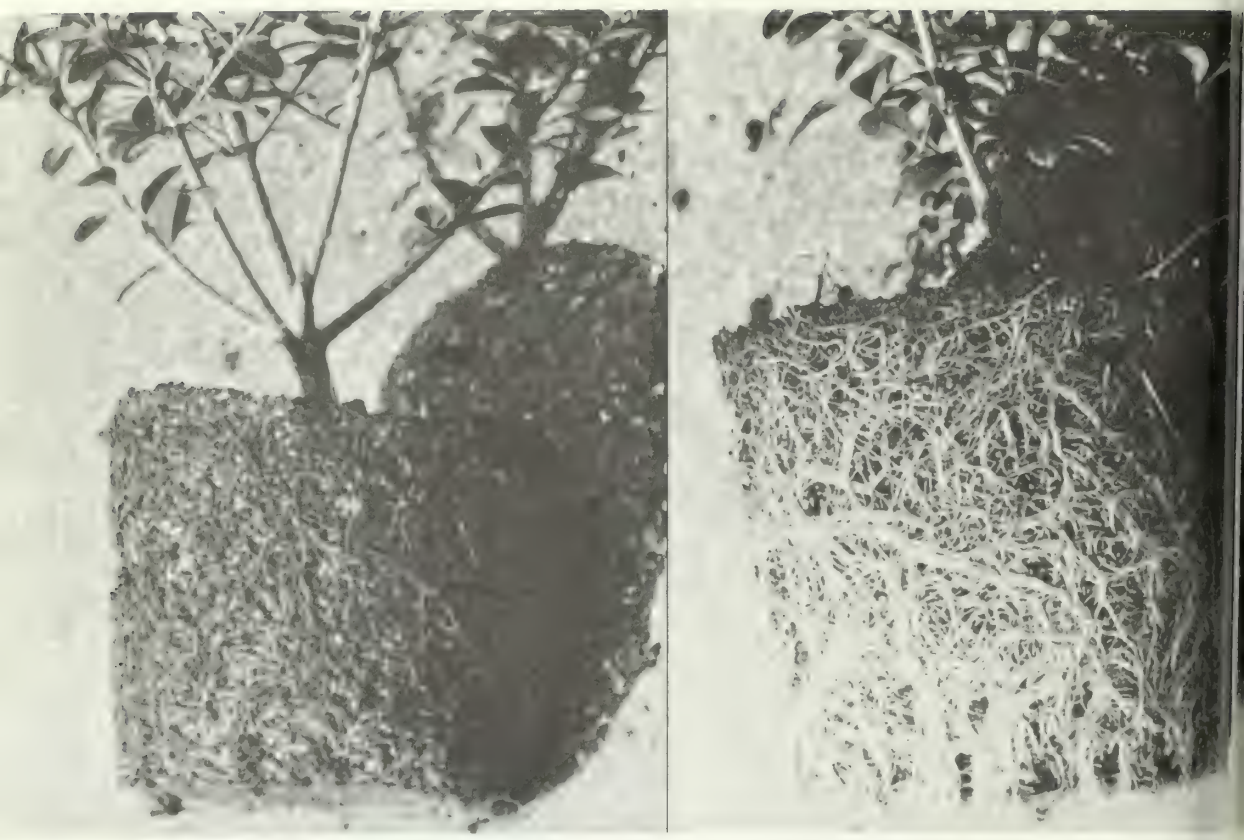


Figure 2.—Plants of Ilex crenata overwintered in containers, but under different conditions. Plant on left was in an unheated, plastic-covered shelter: note the blackness of its roots and the lack of white root tips. Plant on right was overwintered under microfoam: note its active white roots, an indication that its root system was not damaged by cold.

than are plants that lose only their young roots. Plants that suffered no root-kill are more likely to resume normal top growth than are plants that lost either their young roots or both young roots and secondary mature roots. The poor and irregular growth resulting from root injury due to cold is often confused with that caused by damage in transplanting.

## IMPORTANCE OF COLD-HARDINESS OF ROOTS

Plants selected for growing in containers or raised planters should have sufficiently cold-hardy roots. In fact, cold-hardiness of roots should receive primary consideration. Because different species of woody ornamental plants differ in cold-hardiness of roots, selections between species is possible. Less specific information is available on differences between species within genera and between geographic races within species. Presumably species or races growing in widely different climates, such as Florida and Maine, do differ in cold-hardiness of roots. However, from the limited information available (table 1), cold-hardiness of roots within species or races growing within a given climatic area seems to be similar.

The successful growing of ornamental plants in containers or raised planters in the Northeast depends on the proper selection of plants and on sufficient protection of roots during the winter months.

Plants must have sufficiently hardy root systems so most roots can survive the minimum temperatures occurring in unprotected containers, or the containers must be so protected that growing media stay above root-killing temperatures. In the spring of 1970, the City of Manchester, New Hampshire, planted fifty *Gleditsia triacanthos* 'Shademaster' trees (1¼ inch caliper) in concrete raised planters (4 feet in diameter) along its shopping district. Plants were so well cared for during the first growing season that they produced an abundance of new top growth. However, in the spring of 1971 not one of these trees was alive regardless of its location within the shopping district. The most probable cause of death was root kill from low temperatures. *Gleditsia triacanthos* is considered by Wyman *(1965)* to be hardy under air temperature of −10 to −20°F.

## CULTURAL PRACTICES AND THEIR EFFECTS ON ROOT HARDINESS

According to present knowledge, most cultural practices do little to increase the cold-hardiness of roots. Neither additions of plant nutrients nor the use of chemical growth regulators increase the hardiness of roots of woody ornamentals *(Gouin 1969, Havis and others 1972, Mityga and Lanphear 1971)*. Altering the level of plant nutrients in the growing media above or below optimum levels for normal plant growth does not increase root hardiness. Neither foliar nor soil applications of plant growth regulators have increased the cold-hardiness of roots over winter.

Little is known about the mechanism of cold injury to roots of woody plants and the chemical or morphological factors that determine hardiness. If more information about these factors were known, it might be possible to alter cultural practices so as to increase root resistance to cold.

At present, cultural practices most commonly used in preventing root-killing temperatures in containers involve some form of protection. One method used by nurserymen in the Northeast is to irrigate containers biweekly or monthly during the winter storage months. Such irrigation not only delays the freezing of root balls (because saturated root balls freeze more slowly than dried ones); but also thaws, at least partially, root balls that are frozen. Because the water temperature is above freezing, roots are subjected to somewhat higher temperatures than those in unirrigated containers.

An even more effective method of protection than irrigation is the use of microfoam covers. Microfoam is a white, pliable, styrofoam-like packaging material, available in rolls 5 feet wide, 250 feet long, and ¼ inch thick. It is light-weight, has a high insulating value, and reduces light intensity by about 50 percent.

To use microfoam for protecting container stock overwinter, first water the plants thoroughly in late fall or early winter and allow the containers to drain for 24 hours. Then in a well-drained area lay upright plants on their sides and leave spreading plants standing. Pack the plants tightly together, but expose as much of the foliage to light as possible. Cover the plants with a layer of microfoam so that the edges touch the ground. Several sheets may be taped together to form a wide blanket. Cover the microfoam with white polyethylene plastic and seal its edges to the ground with soil. In late winter or early spring, uncover the plants and stand upright those that were laid on their sides.

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# CONTAINER TREES FOR USE IN LANDSCAPING

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*ABSTRACT.* In planting trees, the current trend is to place increasing numbers in containers rather than in the ground. Conditions provided by containers are far from ideal: greater root hardiness is required than in trees planted in the ground. Methods and soil mixtures for improved growth in containers are described. Tree species especially suitable for planting in containers in the various climatic zones are briefly discussed, along with objectives for improving them for container use. Selection and breeding of new clones adapted to container growing are greatly needed.

THE USE OF TREES growing in containers as elements in landscape design is certainly not a new concept. They were a decorative feature of palace buildings in Egypt in the reign of Thutmose III (1430 B.C.), and the famous roof gardens of Babylon, built around 580 B.C., were one of the Seven Wonders of the ancient world. All of the vegetation in these "hanging gardens", as they were called, was grown in containers and container beds elevated one to several stories above the ground level.

An increasing number of city parks are in effect becoming container operations. More and more of the smaller city parks like Union Square in San Francisco and Mellon Square in Pittsburgh are giant container gardens on top of parking garages. In many places, to reduce construction costs, parks are stripped of topsoil, garages are built and roofed over; and then a deep layer of soil is placed on the concrete roof, and new vegetation is planted. This vegetation grows in what is actually a large container, with no access to subsoil water reservoirs as in natural soils.

## CONTAINER GROWING

In the downtown areas of the modern city, most shade trees must be grown in containers. These may be concrete bowls or tubs placed upon the sidewalk, or they may be planting pits below the surface of the sidewalk. Even though the trees appear to be growing normally in soil, the area below the sidewalks is usually a maze of pipes, utility conduits, cellar space, or subways, with little soil.

Trees will not live forever in containers; but if the containers are large enough, several decades of successful growth can be obtained. There are bonsai trees living today that are 100 or more

years old. However, bonsai trees are so small that they can be removed from their bowls at frequent intervals to prune the roots, renovate the growing medium or replace it with new soil, and thus achieve the new root growth essential for the long life of any tree. Street trees growing in really large containers are so massive and heavy that the periodic drastic removal of trees and renovation of soil, essential steps in successful bonsai culture, are not possible. The best that can be accomplished—and it is very rarely done—is a partial removal of the container mix and replacement with new or enriched soil.

### Proper Soil Mix

For this reason the nature of the soil mix in tree containers is of vital importance. To support a relatively long tree life, the soil mix must have certain properties, because it is all that the roots will have access to. They have nowhere else to go; they cannot grow down into the underlying pavement. This soil mix must have a porosity permitting the ready entrance of life-giving air and water and it must drain well enough to prevent stagnation. At the same time, the mix should retain a maximum of moisture without becoming waterlogged.

In such a mix, irrigation can be kept to a desirable minimum, and soil nutrients will not be leached out quickly. Humus, in the form of peat or similar organic substances, is the traditional material used to provide these essential properties in a soil mix for open ground. However, where trees are to be grown permanently in containers, a high proportion of humus in the mix is undesirable because it is soon used up by soil bacteria and fungi. As it disappears, the soil gradually subsides and compacts. A much more permanent substitute for humus as a soil conditioner is a porous inorganic material such as perlite or calcined clay particles. Vermiculite is also longer lasting than humus, but less permanent than the two mentioned above. Some humus content is valuable to promote growth after the tree is planted, but it should not exceed 10 percent of the volume of the mix.

One successful mix that has been tested widely is 45 percent (by volume) of sandy loam (Sassafras loam or a similar type), 10 percent sphagnum peat of a coarse grade, 25 percent horticultural-grade perlite, and 20 percent calcined clay particles (Turface or similar product). To this are added enough ground dolomitic limestone to bring the pH up to 6.0 if the soil is acid, superphosphate at a rate of 2 pounds per cubic yard of mix, and a small amount of fritted trace elements. If only a silt loam or clay loam is available as the soil component, it should be lightened by the addition and thorough incorporation of sand, or else the inorganic soil lighteners can be increased and the soil proportion decreased. If the available soil is strongly alkaline, the pH should be reduced by the addition of aluminum sulphate.

A good medium is essential for survival and continued growth of the trees. The failure of container-planted trees after a couple of seasons of growth has sometimes been blamed on a lack of hardiness of the species or clones used, when in reality rapid compaction of the soil in the containers was the cause.

### Container Size

Another factor is the size of the container. The larger the containers, the better the survival and life expectancy of the trees planted in them. A general tendency is to choose containers that are too small. Trees grown in them rapidly reach a size at which there is very little leeway in watering. Defoliation or death of trees in small containers (2½ feet or less in diameter) can occur quickly in hot summer weather, especially if there is also a strong wind blowing. The older and larger the trees, the shorter the time they can survive without watering. In cold climates small containers freeze more rapidly and root temperatures drop much

lower than in large ones. The cold-hardiness of the roots of many trees and shrubs is much less than that of their aerial parts.

Root hardiness is the really critical factor, as many northern container nurserymen have learned to their sorrow. This factor has not been worked out for most trees, and much additional research is needed for clarification. It is safe to generalize that containers should be at least 3 feet in diameter and 2½ feet in depth and that, wherever space will permit, much larger containers should be used. Very tall narrow ones, besides being unstable in wind storms, freeze in rapidly from the sides. Very broad shallow ones, while stable and aesthetically pleasing, freeze inwardly very rapidly from the top and bottom, and they dry out with excessive speed in summer.

## SELECTION OF TREES

### Importance of Provenance and Species

The colder the climatic zone in which container planting of trees is undertaken, the greater are the difficulties of overwintering and the more limited is the list of varieties that will succeed. It is no accident that large-scale container production of nursery stock is limited to areas where winter freezes are rare or absent. In the selection of trees for container use, *provenance* is much more important than clonal selection. The geographical origin of tree races is a field to which foresters have paid far greater attention than have shade-tree producers. Foresters have done much research, but their efforts have been limited largely to species grown for timber or Christmas trees, mostly conifers such as loblolly and shortleaf pine, Norway spruce, Scotch pine, and Douglas-fir, which are not used for street-tree planting. In the field of ornamentals the surface has barely been scratched.

Trees and shrubs of foreign origin are a good example. Almost all of them have been propagated from a single origin, often an introduction dating back to the 19th century or earlier. Most of the Chinese and Japanese species came from sources close to major port cities, naturally enough, and little or no further exploration has been done for hardier or superior races. There is no question that in many cases far hardier races are waiting to be discovered and introduced. A good illustration is the Siberian elm *(Ulmus pumila)*. The first introduction was not winter-hardy in the prairie provinces of Canada. Later, a strain from a much colder area of the Amur River valley in China, raised by F. L. Skinner, proved to be fully hardy even at Dropmore, Manitoba, where the older strains were not.

Nor has research advanced appreciably farther in the case of our native woody ornamentals. Some tree species like *Cladrastis lutea* are very localized, with a restricted natural range. Many others, however, have an enormous geographical range such as American beech, northern red oak, and red maple, of which various races are native from Canada to Florida or Georgia. Red maples from the northern fringe of their range in Minnesota are among the hardiest of our broadleaf species, while those from the lower end of Florida are scarcely hardier than orange trees. For the Southern States, the provenance of shade trees is just as important as in the North, but heat tolerance is the important factor. Beech or hemlock propagated from New Hampshire seed grow feebly at best in low elevations of Alabama and the Carolinas. The same species grown from seed collected in Tennessee or Georgia make fine, vigorous specimens.

Container culture of landscape plants is relatively easy in areas with mild winters but increasingly difficult in successively colder zones. (Zones mentioned in this paper are those of Arnold Arboretum.) From Zone 6 north, it is increasingly likely that above-ground containers will freeze solid in winter, and furthermore that the soil temperature will drop

below 20°F, which appears to be the critical temperature for the root survival of many woody plants. For such areas, trees that are to be grown permanently in containers should be selected from northern races. Under natural conditions in Zone 5 the ground does freeze in winter, but it does not freeze very deep and the temperature within the frozen layer of the soil does not drop very low. In Zone 3 and the northern parts of Zone 4 the ground freezes on occasion to a depth of 3 or more feet and the soil temperature in the frozen part drops well below 20°F. Therefore in effect, a container tree in a severe winter in Zone 5 is really experiencing the winter root conditions of a much colder zone, and a race or clone originating from the latter will be much more likely to survive.

There is considerable evidence to indicate the importance of root hardiness as a factor for container landscaping. Exceptionally severe winters have played havoc with apple orchards in the northern states on several occasions. When there was little or no snow cover, the ground has frozen to great depths and entire orchards have been wiped out. In at least one instance, scions collected in the early spring, and bench-grafted on apple seedlings overwintered in protected storage, united and grew off normally, whereas the parent trees from which the scions were taken died as soon as the weather warmed up in late spring. It was the roots and not the trunk and branches that were killed. Experiences of this kind led to the use of the extremely hardy *Malus baccata* as an understock for northern orchards, and it is a preferred understock for ornamental crab apples destined for container culture.

From zone 7 south, cold-hardiness of the roots is not a serious problem. Winter protection may still be required for small ornamentals in 1- and 2-gallon cans. However, temperatures do not drop nearly so low as in the North, and freezes are of short duration. Plants of landscape size in large containers do not require protection because the large soil masses take a long time to freeze. Even if they do freeze, the soil temperature within such large containers does not drop to critical levels. Cultural problems are more likely to center on soil temperature during the summer months. As might be expected, races and clones of southern origin will perform much better than those from the far North. Unfortunately, although there has been some interest in selecting clones with superior cold resistance, little or no attention has been paid to selection for performance in the southern part of the range of most important trees.

In zone 9 and the southern parts of zone 8, the question of winter chilling requirements becomes interesting. *Cornus florida* seedlings grown from seed of Connecticut or New York races not only scorch badly in summer in these zones, but also break dormancy irregularly and poorly in the spring, whereas seedlings from local races grow normally. The original (and most widely grown) clone of *Cornus florida rubra* originated in Pennsylvania and will not thrive in Florida, although very southern races of *Cornus florida* are entirely satisfactory. Much work has been done on the dormancy behavior of the orchard peach *(Prunus persica)* and special clones with short-term chilling requirements have been selected for planting in southern orchards. Similar research is needed for shade and ornamental trees. Races of local origin are needed for successful landscape planting either in the open ground or in containers, races with short chilling requirements as a prelude to normal spring growth and with good tolerance of summer heat. From these adapted races clonal selections can be made for superior foliage, flowers, and branching habit. Many nursery growers and landscape designers are aware of the necessity to plant cold-hardy strains in northern zones, but few indeed realize that well-adapted southern strains are equally necessary for warm zones. The poor appearance of some landscape plant-

ings in the deep South is a result of neglecting this important factor.

Moisture stress is a problem with container trees, in inverse proportion to the size of the container used. Unless a careful maintenance program is followed—and this is much more the exception than the rule—soil moisture in containers will frequently approach the danger point. This is most troublesome during summer months when natural rainfall is undependable, daytime temperatures are high, and strong drying winds are frequent. Even if container trees are not killed outright, marginal scorching of the leaves is frequent, and partial defoliation may occur, both of which seriously mar the appearance of the trees.

In view of these problems, the logical approach is to select for container landscaping trees that are pioneer species ecologically and to avoid those that are climax species. The pioneer species are those that first colonize open land, and millennia of adaptation have conditioned them for surviving exposure to sun and wind. Thus, *Juniperis virginiana* or *J. scopulorum* will stand moisture stress that would kill *Tsuga canadensis*. Likewise *Quercus macrocarpa* or *Q. prinus* will thrive where *Acer saccharum* or *A. pensylvanicum* will not.

In the production of container trees for landscaping, provenance is just as important for drought-tolerance as it is for cold-hardiness. Trees like many of our native oaks and maples, which have a wide longitudinal range, from the humid East Coast to the edge of the dry Plains States, exhibit marked differences in moisture requirements. Races from the driest part of the species' range have a much greater potential for container use than races from areas with abundant natural rainfall. The former also tend to have a slower growth rate and smaller size at maturity, which extend their life and usefulness in the restricted soil of containers. They exhibit great clonal variation, and it is not difficult, in even the best geographical races, to select and propagate clones of marked superiority for container landscaping.

### Resistance to Diseases and Insects

Natural resistance to insect pests and fungus diseases is desirable for all shade trees. It is even more important for trees destined for container use. Such trees are already struggling with adverse environmental conditions and do not have the reserves to survive an attack. The trees are usually located in enclosed courtyards, on raised roof gardens, or in other areas with poor access for spraying equipment. There is usually dense pedestrian traffic in such locations too, which means that spraying must be done during night hours if it is to be done at all. For these and other reasons, preventative maintenance is likely to be minimal, and natural resistance is especially desirable.

Enormous efforts—so far unsuccessful—have been made to find clones with natural resistance to spectacular lethal diseases like chestnut blight and Dutch elm disease. Much less attention, if any, has been paid to selection and breeding for resistance to nonlethal but disfiguring diseases and insects. There is great clonal variation in disease resistance. For example, *Malus* 'Hopa' is especially susceptible to defoliation from apple-scab disease *(Venturia inaequalis)*, whereas *Malus* 'Zumi Calocarpa' and clones of *Malus baccata* are virtually immune. Powdery mildew (*Sphaerotheca* sp.) badly disfigures the English oak *(Quercus robur)*, but occasional individuals occur that are free of it. Similarly there are occasional rare specimens of horsechestnut *(Aesculus hippocastanum)* that do not get the leaf blotch disease *(Guignardia aesculi)*, which defoliates the normal individuals by midsummer in many areas.

Marked resistance to insect pests is less frequently observed than resistance to fungus diseases, but it does occur. When the American elm was the largest selling species of all shade trees, our firm used to propagate a clone with exceptional resistance to the elm leaf beetle

*(Pyrrhalta luteola)*, but we abandoned it when the Dutch elm disease stopped the planting of elms. When the Japanese beetle *(Popillia japonica)* reached the climax of its abundance in New Jersey 40 years ago, our firm selected and for a time propagated a clone of *Tilia cordata* that was virtually untouched by the pest.

The time is now ripe for serious attention to selection and breeding for natural resistance to insects and fungi.

## SPECIES WARRANTING ATTENTION

Most of the following species were included in the American Horticultural Society's preliminary listing of trees that show special tolerance for urban growing conditions. The species are grouped arbitrarily under the coldest climatic zone in which they are reliably hardy, as a convenience for tree breeders who are working in these particular zones. However, the same species are very useful for container use in warmer climates.

### Zone 2

*Acer negundo* (boxelder).—A poor choice wherever better maples are hardy, but useful for its extraordinary hardiness. Strains from the extreme northern edge of its range should be used for selection work.

*Aesculus glabra* (Ohio buckeye).—The hardiest of all the *Aesculus* species, free from leaf blotch disease, and some individuals show very good fall color. Can be hybridized with *A. hippocastanum* for a cross having much more showy flower trusses. The hybrids are very light fruiters, an advantage in a container tree.

*Betula papyrifera* (paper birch).—The best of all the white-barked birches for resistance to bronze birch borer. Seedling populations also exhibit wide variation in susceptibility to birch leaf miner, a difficult pest to control in the eastern part of the continent where it is native. Individual seedlings also vary in the age at which their bark turns white. Other qualities being equal, individuals that attain white bark early in life are superior for ornamental purposes.

*Prunus maackii* (Amur chokecherry).—One of the most ornamental of the small cherries, with polished yellow-brown bark. Selection objectives would include a more upright growth habit and larger racemes of flowers.

*Prunus padus* (European birdcherry).—The most showy-flowered of the very hardy cherries. There have been many European selections, two of which deserve re-introduction into the nursery trade after heat treatment to clean up virus problems. These are the variety "Watereri", which bears racemes of larger-than-normal flowers up to 8 inches in length, and 'plena', which bears semi-double flowers that last much longer than the single-flowered types.

*Syringa amurensis japonica (S. reticulata)* (Japanese tree-lilac).—A fine small tree bearing showy heads of white flowers in early summer. Seedlings vary in habit of growth and in size and density of the flower panicles. The cultivar 'Ivory Lace' from Canada is indicative of the improvement that even simple selection can produce.

*Ulmus pumila* 'Dropmore' (Dropmore Siberian elm).—This strain has remarkably superior hardiness in comparison with the species in general. A large seedling population of the Dropmore strain would yield some cultivars with greatly improved form since, like all elms, it is a very variable tree.

### Zone 3

*Acer ginnala* (Amur maple).—One of the hardiest of all maples, with a clean habit and outstanding fall color. Most seedlings are very twiggy and tend to produce crooked trunks. Occasional individuals have marked apical dominance and produce straight trunks with fewer side branches, a form that can be readily pruned into standard tree form.

*Celtis occidentalis* (common hackberry). This species is particularly well

adapted to container use because its roots are very tolerant to cold. It has a great latitudinal range, and northern genotypes should be used. Selection should emphasize natural resistance to witches' broom, the scourge of the species.

*Malus* cultivars (crabapples).—Most are not winter-hardy north of zone 4, but *Malus baccata* and its descendants are much more cold-tolerant and also have the desirable trait of high resistance to apple-scab disease. Objectives should include double and hence sterile flowers, a wide range of colors, and natural resistance to both apple scab and fire blight.

*Tilia americana* (American linden).—Breeding should focus on dense crowns and smaller leaves. The clone 'Redmond' (erroneously reported to be a clone of *T. euchlora*) is an example of the latent potentialities of this very hardy tree.

### Zone 4

*Acer rubrum* (red maple).—Almost all the good clones of red maple, except for the Arnold Arboretum clone 'columnare', are of Zone 5 or 6 origin. There is great need for trees with reliably red fall color, but with greater hardiness than 'October Glory' and 'Red Sunset', especially for container use. In selection, emphasize large and deep-red flowers for spring effect, as these vary enormously in half-sibling seedlings.

*Aesculus hippocastanum* (horsechestnut).—One of the most spectacular of the hardy trees when in flower. Breeding should concentrate on large floral trusses and freedom from leaf-blotch disease. Hybridization with other species can greatly increase the color range of the flowers, but the progeny should be ruthlessly culled for freedom from foliar diseases.

*Amelanchier* sp. (shadblow or serviceberry).—This genus has been badly neglected, but has great ornamental potential. Objectives would include double or at least semi-double flowers, a good non-fading pink clone, and selection for fall color, which is variable.

### Zone 5

*Pyrus calleryana* (Callery pear).—New clones are coming on the market, but the species still has unrealized potential. Double flowers (which will extend the length of blooming display), improved winter hardiness, and more brilliant fall color are all important goals. Callery pear thrives in city conditions.

*Sophora japonica* (Pagodatree).—An exceedingly variable species. Improved growth habit, partial or preferably total sterility by means of double flowers, and the production of a better clone with violet flowers should be sought.

*Zelkova serrata* (Japanese zelkova).—The best selections are promising substitutes for American elm. Existing races come from a very limited—and by no means the most cold-hardy—provenance.

### Zone 6

*Corylus colurna* (Turkish filbert).—A rare, but very fine tree, pyramidal in form, with clean foliage and marked resistance to drought. Seedlings vary considerably in shape and foliage, and the best forms are well worth selection and vegetative propagation.

*Crataegus phaenopyrum* (Washington hawthorn).—The best of all the *Crataegus* species for city use, it is very tolerant of city conditions, with first-rate flowers, foliage, and fruit. Not very variable, but superior individuals do occur. Breeding objectives would include adding color in the flowers, less pendant lower branches at maturity, and thornlessness.

*Prunus cerasifera* (myrobalan plum).—An excellent container plant, tolerant of confinement and resistant to drought. All named clones were selected for the deep color of their purple foliage. Cultivars with less purple foliage, more vigorous growth, and larger and more richly colored flowers would be a great improvement.

*Maclura pomifera* (Osageorange).—Tough, hardy, and very drought-tolerant. Dioecious, so only male clones should be

used. Selected clones have a fine erect branching habit and excellent lustrous foliage. The bark is handsome in winter.

### Zone 7

*Celtis australis* (European hackberry).—An excellent shade tree, reaching noble stature on open ground, but also withstanding confinement. It is not subject to witches' broom. The species is very variable in the size and quality of foliage, as well as in growth form. No selection has been done.

*Cupressus sempervirens* (Italian cypress).—This evergreen thrives in conditions of heat and drought. The narrow form var. *stricta* is a showy accent plant, and the broadly spreading var. *horizontalis* makes a fine small shade tree.

*Magnolia grandiflora* (southern magnolia).—The finest evergreen flowering tree. Usually seedlings are planted, and quality of their flowers and foliage is very uneven. Some superior named clones of American origin are appearing, but the possibilities for improvement have been by no means exhausted.

### Zone 8

*Lagerstroemia indica* (crapemyrtle).—The few best forms are unequalled as flowering trees in the South. Growing them with multiple stems greatly enhances the attractiveness of their bark. Street forms should be bred for rapidity of growth and freedom from powdery mildew fungus. Dr. Egolf's new creations are especially promising.

*Prunus lusitanica* (Portugal laurel).—This species varies considerably in the thickness of its foliage and resistance to winter burn. It has been grown in the middle South since colonial times, but no selection has been done in this country. It withstands heat and confinement, and the glossy foliage of the best forms is outstanding.

### Zone 9

*Bauhinia variegata* (orchid tree).—The showiest of the genus, in both the normal purple and white forms. Selection should emphasize a more upright growth habit and larger flowers.

*Ceratonia siliqua* (carob tree).—A clean tree with remarkable resistance to heat and dry soil. Many forms are scrubby and contorted in shape, but good ones with superior foliage do occur and would form a parental nucleus for improvement.

*Olea europeae* (olive).—One of the best of all container trees on the West Coast. Breeding efforts have been limited largely to improving the species for orchard purposes, the diametric opposite of ornamental use. Improved form, foliage, and partial or complete sterility would be the proper goals for breeding ornamental olives.

*Quercus virginiana* (live oak).—A strong contender for the title of the best of all the evergreen oaks. Highly variable in leaf size, leaf gloss, duration of foliage retention, and branching habit. At present only mediocre seedling trees are planted.

### Zone 10

*Delonix regia* (flamboyanttree).—The showiest of all flowering trees. Long-lasting in a big container, and tolerant of adversity.

*Ficus retusa* (Indianlaurel fig).—Very broad and spreading, handsome evergreen. Most trees observed in this country and Puerto Rico appear to be a single clone. Better forms may exist in its native region.

*Jacaranda acutifolia* (sharpleaf jacaranda).—Most jacarandas sold are of seedling origin, and they vary considerably in size of the floral truss, size and color of the flowers, and length of time the foliage is retained. The genus is tolerant of root confinement.

## CONCLUSION

The species noted above are by no means the only possibilities for container use. However, they do include many well adapted to container growth and were selected because they have received little or no attention from ornamental tree breeders. In my opinion they warrant more work by tree breeders.

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# SELECTION AND BREEDING OF MAPLES FOR URBAN AREAS

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*ABSTRACT.* Among its approximately 150 species, the genus *Acer* offers diversity in size, form, color, and adaptability. Genetic improvement of maples for urban environments will require studies of intraspecific variation, interspecific hybridization, and tolerance to *Verticillium* wilt and environmental stresses. Breeding and selection with small exotic maples has been neglected, yet might rapidly yield improved cultivars of high value for urban plantings.

THE MAPLES may constitute the most important group of trees available for planting in metropolitan areas. Among about 150 species, the maples offer great diversity in size, shape, leaf and fruit characteristics, and leaf coloration *(Mulligan 1958; May 1961, 1962)*. Moreover, most of them are easy to transplant, are long-lived, and grow well in a variety of soil conditions *(Irwin 1973)*. Most of the Japanese, Chinese, and Himalayan species are shrubs or small round-headed trees—just the size so much in demand for urban plantings. The genus *Acer* offers a virtually untapped genetic resource.

The genus extends over a major part of the northern hemisphere, and is found in almost all countries north of the Equator to Alaska and Siberia *(May 1961, 1962)*. South of the equator, species have been reported in Sumatra and Java.

Mulligan *(1958)* gave their distribution as follows: China, 58 species; North America, 25 species; Japan, 16 species; Europe, 13 species; Taiwan, 11 species; southeastern, western, and northeastern Asia, 16 species; India and Burma, 6 species, and Korea, 5 species. The greatest diversity of species, or principal center of the genus, is found in the eastern Himalayan Mountains and western China.

## CYTOLOGY

The basic chromosome number in the genus *Acer* is n = 13. Of the approximately 46 species examined for chromosome number, 42 have been reported as diploid *(Wright 1957, Mehra and others 1972)*. *Acer saccharinum, A. pseudoplatanus,* and *A. carpinifolium* are tetraploid *(Wright 1957)*. Santamour *(1965)* reported that trees of *A. rubrum* may exist as a hexaploid, octoploid, or septaploid. Aneuploid hybrids between red and silver maples are also possible.

## TAXONOMY

The only comprehensive monographs of the genus are those of Pax *(1902)* and Murray *(1970)*. Pax listed 13 sections of the genus: *Platanoidea, Campestria, Saccharina, Spicata, Palmata, Glabra, Integrifolia, Indivisa, Macrantha, Lithocarpa, Rubra, Trifoliata,* and *Negundo.* Rehder *(1940, 1949)* later recognized only two sections, *Acer* and *Negundo.* Section *Acer* contained 13 series, which corresponded to 12 of Pax's sections plus Rehder's *Arguta.* Critchfield *(1971)* surveyed maples with medium-size or small leaves and grouped the species into four categories based on shoot growth and heterophylly. His findings agreed with the taxonomic classifications of Pax *(1902)* and Fang *(1966)*. He emphasized, however, that past failure to recognize and deal with heterophylly in *Acer* has imposed unnecessary restrictions on the scope and usefulness of maple classification.

Murray *(1970)* divided the genus *Acer* into seven subgenera, and these into lower sections and series. According to this scheme, the subgenus *Acer* contains most species and is split into 16 sections. Fowden and Pratt *(1973)* surveyed the occurrence of cyclopropylamino acids and examined their pattern of distribution against Murray's classification. The ability to synthesize these acids was restricted to the members of certain sections; and when several species from an individual series were analyzed, all showed a common pattern. One species, *A. distylum,* was characterized with a single ninhydrin-positive compound. Momotani *(1962)* had reported previously that *A. distylum* exhibited certain unique features of seed protein composition.

Ziegenfus and Clarkson *(1971)* used polyacrylamide disk electrophoresis, immuno-electrophoresis, and double diffusion to compare seven taxa of *Acer* native to eastern North America. The members of the section *Saccharina* were found to have close protein similarity. *A. negundo,* thought by several workers to be the most distinct of the maples, was found to have high protein similarity with the members of the section *Saccharina.* The traditional placement of *A. rubrum* and *A. saccharinum* in the same section was supported by the relatively high protein similarity of these taxa. Data obtained by serological techniques and disk electrophoresis were found to be complementary. Thus these chemical experiments confirmed morphological and genetic evaluations of the relationships among species.

## INTRASPECIFIC VARIATION

Wide variation within a species allows for rapid genetic progress, because initial selection of the best populations gives a superior base from which advances can be made. The larger and more variable the array of phenotypes available for selection, the greater are the prospects for genetic improvement. It is important, therefore, to determine the magnitude of genetic variation within each maple species. Little research has been directed to this end, even though most maples grow over a wide range of habitats.

Sugar maple *(A. saccharum)* has been more intensively studied than any other maple species. Much of the research has uncovered considerable variation in timber quality *(Kriebel 1968)*. In a summary paper, Kriebel and Gabriel *(1969)* reported marked variation in winter hardiness, tolerance to summer heat and drought, chilling requirements, time of onset of dormancy, branching habit, growth rate, and sugar concentration. Narrow-crown types could be selected from Appalachian and northern origins. Drought-resistant genotypes of intermediate size and bushy crown could be made from trees native to southern Illinois and possibly southern Indiana. For the South, the Florida sugar maple (subspecies *floridanum)* offers excellent possibilities for selection of compact types of small size at maturity.

A red maple *(A. rubrum)* seed source and progeny test we have carried out at

Delaware, Ohio, has shown considerable variation in fruit traits, height growth, autumn coloration, time of flushing, and cold hardiness *(Townsend 1972, 1975)*. We have also uncovered significant variation in tolerance to drought *(Townsend and Roberts 1973)*, *Verticillium* wilt *(Townsend and Hock 1973)*, and air pollution *(Townsend and Dochinger 1974)*. Important information on adaptability of different seed-source progenies will be forthcoming from performance evaluation of progenies outplanted in Ohio, Indiana, Iowa, Michigan, Missouri, Wisconsin, and Minnesota. We also have established two urban plantings of red maple progenies, one in Cleveland and another in Pittsburgh, to determine which groups can best tolerate urban stresses.

Wright *(1949)* found pronounced genetic differences between wild trees of silver maple *(A. saccharinum)* growing in a limited geographic area. There were significant differences among progenies in the amount of winter-killing and in the number of branchlets that developed in the axils of uninjured leaves on the current year's growth.

Research related to intraspecific variation in other *Acer* species has been very limited. Demos and others *(1973)* grew *A. negundo* under both indoor and outdoor conditions. Seedlings were grown from seed collected from New York, Ohio, Tennessee, and Texas. Frost resistance increased as the length of the growing season at the seed origin decreased.

## BREEDING

Little research has been concentrated in determining interspecific crossability patterns in *Acer*. Freeman *(1941)* produced *A. rubrum* x *saccharinum* hybrids. Wright *(1953)* attempted 35 different interspecific combinations. *A. platanoides* x *mayrii* and *A. platanoides* x *cappadocicum* grew vigorously after outplanting and showed hybrid vigor in their tenth year *(Wright 1962)*. *A. negundo* x *henryi* hybrids outgrew the female parent in the nursery, but later suffered winter dieback. Wright believed that in warm temperate climates this hybrid would be a promising ornamental because of its foliage, which remains pink or red during the summer.

Table 1 is a summary of reported hybridizations in the genus *Acer*. Many of the hybrids have been reported without essential morphological and biochemical data to verify hybridity. Albenski *(1946)* reported success in these crosses: *A. negundo* (♀) x *A. saccharinum* (♂), *A. negundo* (♀) x *A. platanoides* (♂), and *A. platanoides* (♀) x *A. negundo* (♂). However, insufficient information is given to conclude that true hybridity was present. As indicated in table 1, Zaikina *(1959)* reported success in eight crosses among nine species. Little evidence was given, however, to verify hybridity.

Genetic barriers to crossing seem to be present between species belonging to different sections. Many within-section crosses are possible. Wright *(1953)* reported that none of 24 attempted crosses between species belonging to different sections was successful.

Piatnisky *(1934)* ran experiments on selfing of 10 *Acer* species. Unfortunately, he did not germinate the seeds to determine the quality of seeds. For all species, a larger percentage of unfilled fruit developed from self- as compared to cross-pollination.

Inbreeding experiments with sugar maple have shown that there are significant differences between individual trees in self-fertility *(Kriebel and Gabriel 1969)*. Seed set in terms of numbers of flowers pollinated ranged from 8 to 27 percent. The close relation of percentage seed set after self- and cross-pollination of a given female parent indicated that self- and cross-sterility were associated.

The expression of agamocarpy is strong in sugar maple: fruit sets ranging from 36 to 94 percent were noted among unpollinated flowers of individual trees *(Gabriel 1967)*. However, less than 1 per-

Table 1.—Reported hybridizations in the genus Acer

| Female parent | Male parent | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *platanoides* | *mayrii* | *cappadocicum* | *lobelii* | *campestre* | *monspessulanum* | *saccharum* | *macrophyllum* | *pseudoplatanus* | *tataricum* | *palmatum* | *japonicum* | *rufinerve* | *barbinerve* | *rubrum* | *saccharinum* | *henryi* | *negundo* |
| *A. platanoides* | .. | S-5 | S-5 | S-4* | .. | .. | F-5 | .. | .. | .. | F-5 | F-5 | .. | S-6 | S-6<br>F-5 | S-6 | F-5 | S-1, 6;F-5 |
| *A. lobelii* | S-4* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *A. miyabei* | .. | .. | .. | .. | S-3 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *A. campestre* | .. | .. | .. | .. | .. | S-4* | .. | .. | S-4* | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *A. monspessulanum* | .. | .. | .. | .. | S-4* | .. | .. | .. | S-4* | S-4* | .. | .. | .. | .. | .. | .. | .. | .. |
| *A. opalus* | .. | .. | .. | .. | .. | S-4* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *A. saccharum* | S-5 | .. | F-5 | .. | F-5 | .. | .. | S-3 | .. | .. | F-5 | .. | .. | .. | F-5 | F-5 | .. | F-5 |
| *A. pseudoplatanus* | S-6 | .. | .. | .. | S-4* | S-4* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| *A. buergerianum* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | F-5 | .. | .. | .. | .. | .. | .. | .. |
| *A. tataricum* | S-1 | .. | .. | .. | S-1 | S-4* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | S-1 |
| *A. palmatum* | F-5 | .. | .. | .. | .. | .. | F-5 | .. | .. | .. | .. | F-5 | .. | .. | .. | .. | .. | F-5 |
| *A. davidii* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | S-3 | .. | .. | .. | .. | .. |
| *A. pensylvanicum* | .. | .. | .. | .. | .. | .. | .. | .. | .. | S-4* | .. | .. | .. | .. | .. | .. | .. | .. |
| *A. rubrum* | S-6<br>F-5 | F-5 | F-5 | .. | F-5 | .. | F-5 | .. | .. | .. | F-5 | .. | .. | .. | .. | S-2,5 | .. | S-6<br>F-5 |
| *A. saccharinum* | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | S-5 | .. | .. | .. |
| *A. negundo* | S-6,1 | .. | .. | .. | .. | .. | F-5 | .. | .. | .. | .. | .. | .. | .. | F-5 | S-1<br>F-5 | S-5 | .. |

* Direction of cross unknown.
S = Success in obtaining hybrids.
F = Failure in obtaining hybrids.

1 = Albenski *(1946)*
2 = Freeman *(1941)*
3 = Mulligan *(1958)*
4 = Rehder *(1940)*
5 = Wright *(1953)*
6 = Zaikina *(1995)*

cent of the unpollinated flowers produced filled fruits.

Details of flower ecology and flower morphology of *Acer* have been described by Mottier *(1893)*, Taylor *(1920)*, Stout *(1938)*, and Hall *(1951)*.

For success in interspecific hybridizations, it is essential that we learn much more about sex conditions, time of flower ripening, pollen dissemination and storage, and receptivity in *Acer* species. Most maples can be control-pollinated by using porous or loosely woven bags. Kriebel and Gabriel *(1969)* have found that white cotton bags are suitable; flowers in dark-colored cloth or paper bags are killed by overheating. Pollen can be applied by using freshly opened anthers as pollinating brushes, or from a vial with a camel's hair brush.

## SPECIES WITH IMPROVEMENT POTENTIAL

Many maple species seem to offer essential attributes for planting in metropolitan areas. The introduction and evaluation of exotic species need to be expanded. These species could be used in a selection program, and for hybridization with native and other exotic species. The potential of a species in most cases will be based on its climatic and edaphic requirements. However, the range of adaptability of an exotic species may be increased by hybridization with other species. To develop new maple cultivars of smaller sizes, the following exotics seem to offer the best opportunities for breeding and selection:

*A. argutum*—hempleaf maple. A small tree, it reaches a height of 25 feet.

*A. buergerianum*—trident maple. This species is becoming more and more popular as a street tree, and has performed well in Oregon *(Ticknor 1973)*.

*A. campestre*—hedge maple. This species is especially useful as a screen hedge on relatively dry soils. It is usually pest-free and stress-tolerant, and shows dark green summer foliage and excellent yellow fall color. Kozel *(1974)* highly recommends this tree for planting directly beneath utility lines, based on information derived from a shade-tree evaluation project.

*A. capillipes*—Kisogawa maple. According to Ticknor *(1973)*, this species has grown and colored well in Oregon. Its bark is green with white stripes, and it does better in open areas than striped maple *(A. pensylvanicum) (Mitchell 1972)*.

*A. carpinifolium*—hornbeam maple. The crown is vase-shaped. The leaves closely resemble those of hornbeam, and produce a dense, dark crown. It grows to a height of about 30 feet.

*A. circinatum*—vine maple. Harkness *(1955)* stated that this species has shown brilliant red fall color in Rochester, N.Y., and grows as a shrub on poor soil. This tree is especially suited for urban lots because of its small, compact size, and its ability to grow well in partially shaded locations. Stems commonly are much twisted and turned.

*A. ginnala*—Amur maple. Grows to about 20 feet in height and forms a dense-branching, upright, rounded crown. Reliably cold-hardy, it shows conspicuous red samaras in summer and rich red foliage in fall.

*A. griseum*—paperbark maple. This has light brown bark that separates into paper-thin flakes, revealing orange bark beneath. The chief obstacle to more widespread use is its difficulty in propagation *(Fordham 1969)*. Controlled-pollinations should be attempted to overcome the problem of undeveloped embryos.

*A. nikoense*—Nikko maple. One of the few maples having a vase-shaped form, this species is especially attractive from mid to late October, when its leaves turn rose-red.

*A. spicatum*—mountain maple. The fruit of this species is unique in displaying an autumnal coloration equal or even superior to that of the foliage. Also, it is extremely cold-hardy and tolerates partial shade.

The preceding list includes the most promising small maples. Of the larger maples, *A. macrophyllum*, *A. rubrum*, *A. saccharum*, and *A. platanoides* offer the wide range of variability essential for rapid genetic improvement.

## SELECTION AND BREEDING STRATEGIES

The major objectives of any future research on maples should be: (1) to develop knowledge of the existing and potential variability of native and exotic species of value in metropolitan areas; (2) to provide information and create breeding material that will make possible the development of genetically improved genotypes; (3) to breed, select and release new and more adaptable, maple cultivars.

Approximately 170 cultivars of *Acer* have been selected. Most of these are phenotypes that appear to be exceptional in leaf coloration or tree form. Many are planted widely, and for good reasons *(Davis 1973, Kozel 1974)*. However, none of these has resulted from a scientific systematic program of selection and breeding. As a result, no one cultivar has proved itself above-average in disease or insect resistance, or as especially adaptable to urban stresses. These latter characteristics should be primary goals of an urban-tree improvement program.

It is essential that we investigate the intraspecific variation in the most promising maple species. Establishment of one-parent progeny tests representing a wide range of sources can form the basis for a breeding and selection program and enable recommendations to be made of the best seed sources for seed collection. For example, we at Delaware, Ohio, are planning to select the best clones of red maple from those half-sib families that show the best performance throughout the north-central U. S. We also plan intraspecific crosses between superior clones.

The full potential of interspecific hybridization needs to be explored. Several geographic seed sources of each species should be used to test species compatibility. Hybrids that are developed should be tested in different areas to determine their range of adaptability and usefulness.

*Acer* species should be screened and compared in their tolerance to *Verticillium* wilt, air pollutants, cold, drought, and salt. Basic information is becoming available on the relative ability of different maple species to tolerate salt *(Lumis and others 1975)*. Studies such as these are necessary before an effective *Acer* breeding and selection effort can begin. More must be learned about environmental modifications of tolerance to *Verticillium* wilt, and host-pathogen interactions should be explored *(Dwinell 1967)*.

Research in forest genetics has shown that some stem characters such as straightness and tapering are less dependent on the environment and are possibly controlled by a simpler gene complex than growth rate *(Johnsson 1960)*. Therefore, we may make faster genetic gain on stem or trunk properties than on growth rate. In many species examined to date, the tendency of the stem to grow straight is associated with the geographical origin of the seed.

It is important that, once developed, promising clones should be planted in metropolitan areas, to be tested for adaptability to the composite of stress factors present in the city. The urban tree geneticist must take responsibility not only for developing better trees, but also for assuring that their superiority is retained under adverse conditions.

Also needed are studies related to flora morphology and dichogamy, and apomixis. Problems of vegetative propagation must be overcome if promising species such as paperbark maple are to be used in an improvement program. Selection and breeding should include the improvement of specific rootstocks that would enable

trees to grow in containers or urban areas where root-growing space is limited.

## CONCLUSION

Genetic improvement of maples will require cooperation among geneticists in federal agencies, geneticists in universities, nurserymen, arborists, and other specialists. All species of maples constitute a large reservoir of diverse trees that can be used for planting in metropolitan areas. Highest priority should be given to selecting, breeding, and testing of genetically identified progenies and clones.

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# CHAPTERS ON THE GENETIC IMPROVEMENT OF ELMS

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*ABSTRACT.* The development, goals, and newly released clones of the Dutch elm breeding program are described. The merits of clonal and seedling varieties are compared; the latter have some advantages for landscaping purposes. They also contribute to gene conservation. In preparing for future disease risks, however, variability *per se* is valuable, be it through clones or seedlings. The recent variation in the fungus *Ceratocystis ulmi* is discussed; and two types of resistance are described. The value of Asiatic elms is stressed. Reasons for the slow progress in the improvement of American elm are given, and research needs are mentioned.

ELM USED TO BE the favorite tree for urban use over large areas of the northern hemisphere. It would still be so, if the Dutch elm disease, caused by the fungus *Ceratocystis ulmi* and spread by various elm bark beetles, had not appeared. The disease wrought havoc among the elms of Europe, North America, and parts of Asia; so that elm was no longer safe for new plantings.

Breeding now should serve to give the elm back to the city and landscape forester, as a tool to beautify man's world. In this paper I do not intend to give a complete survey of elm-breeding programs, but rather to concentrate on some general aspects and on some questions of current interest.

## PLOTTING A COURSE

Tree breeding is more than just research.

To be effective, a breeding program should constantly readjust its course by confronting the desirable and the attainable. The breeder should try to develop the full picture of each as completely as possible, and then confront the two. At the start of the Dutch elm breeding program around 1930, the goal considered desirable was to develop a clone that was resistant to Dutch elm disease, was fast growing, and had exactly the same shape as the existing and popular clone *U.* x *hollandica* 'Belgica'. Subsequently, we found quite feasible the production of resistant and fast-growing trees; but, surprisingly, the production of a clone with the shape of 'Belgica' has proved as yet unattainable.

One can also proceed by considering first what is achievable, and then find out whether that is desirable. Resistant, fast-growing trees with the shape of Siberian elm were within easy reach, but appeared

not desirable. Similarly, the production of a resistant, small compact elm proved attainable; and more or less to our surprise, city foresters found it desirable, so it was released under the name 'Groeneveld' *(Heybroek 1964)*.

Neither desirabilities nor attainabilities are fully known from the start. The desirability of exposure resistance in clones in Holland was realized only in the course of the program. It was, in fact, only realized after the first two released clones had proved to be failures in this respect. New demands arise with changes in use patterns of tree species. In our country, some need has arisen for elms fit for use in the new forests that are being created near the cities—on formerly agricultural land and in areas reclaimed from the sea. This use allows or requires a different set of properties in the candidate elm.

Experience can try to predict what is attainable. Research, however, can open up new, unthought-of possibilities. Santamour *(1972a, 1974)* showed that it is possible to hybridize fall- and spring-flowering elms so that it is now possible to utilize the disease resistance of the fall-flowering Chinese elm in many new combinations. The availability of new parent material from plant introductions may likewise open up new possibilities. The weighing of desirability against attainabilities and *vice versa* is therefore a continuous process and an important responsibility of the breeder: he should explore both.

The breeder should further try to quantify his wishes. He should try to find out what minimum level of resistance is required, or in other words, how susceptible a tree can be and still be acceptable for practical use. Though absolute resistance may be ideal, it may well happen that, in the absence of the ideal, a tree with no more than moderate resistance would be very welcome, too.

In our program, this led to the realization that we have use for several types of elm for different purposes. Requirements differ for these different types of use (table 1). Under open conditions in the coastal area, where salt-laden winds are frequent, a tree with relatively poor marks for several properties will do, provided it has a high resistance to exposure and to the fungus *Nectria cinnabarina*. The latter can be particularly noxious in that area. For an elm that should profitably be grown under forest conditions, shape and exposure resistance have a low priority; however, the tree should produce good-quality timber in a short time.

## THE DUTCH PROGRAM AND ITS RECENT RELEASES

When Dr. Christine Buisman was first appointed to study the Dutch elm disease and to try to find solutions for it, she started by making a wide collection of clones and seedlings of elm from every available source in 1928-30. S. G. A. Doorenbos, Director of Parks in the

Table 1.—Minimum requirement for elm clones for different uses in the Netherlands (adapted from Heybroek 1966)

| Property | Property rating by type of use[1] | | |
|---|---|---|---|
| | General | Coastal areas | Forest for timber |
| Resistance to Dutch elm disease | 2 | 3 | 2 |
| Shape | 3 | 4 | 4 |
| Growth rate | 3 | 4 | 1-2 |
| Resistance to exposure | 3 | 1 | 4 |
| Resistance to *Nectria cinnabarina* | 3 | 2 | 3 |
| Timber quality | 4 | 5 | 1-2 |

[1] Rating: 1 = very high/very good for the particular property; 2 = high/good; 3 = medium; 4 = low/poor; 5 = very low/very poor.

Hague, helped her. This material was screened for resistance by artificial inoculation with *C. ulmi*, the causal fungus, in the following years, 1930-36. Absolute resistance would have been preferred, but Dr. Buisman soon found that such resistance did not exist, and that the expression of disease symptoms could vary considerably from year to year. It appeared that resistance was only relative. Therefore, not every seedling or clone with some slight disease symptom was discarded. Though a high proportion of the original material was thrown away because of too severe reactions to the disease, quite a few plants or clones were kept that were not too badly diseased. In this respect, the program resembled that of Cornell University *(Sinclair and others 1974)*.

This policy proved to be right. When the elms started to flower and my predecessors decided to cross them and select among their offspring, a collection of elms with a fair degree of resistance was available, and crosses of these sometimes produced seedlings with a much higher degree of resistance than the parents and with a desirable growth-habit. It was only fortunate the parents had not been discarded. On the other hand, some of the most resistant selections gave a much poorer offspring. The 'Christine Buisman' elm transmitted little of its high resistance to its offspring. Similarly, offspring of the resistant Siberian elm were often disappointing as regards resistance, also generally had an undesirable shape, suffered some twig dieback, and were often incompatible with the commercially used rootstock.

In the scheme of figure 1, the development of the breeding program is exemplified, giving the pedigree of the newly released clone 'Plantyn'. Before its release, it was known as No. 496. This clone was selected in 1962 from a population of hybrid seedlings, made in 1954 from parents as shown. As the grafts showed quality in growth and resistance at an early date, the clone was soon used in crosses. A very good cross was made in 1965 with the equally promising clone 495 (ancestry shown), yielding fine clones that are presently under test. These clones thus belong to the $F_3$-generation.

Completing the story of the 'Plantyn' elm, I can add that its grafts entered field tests as early as 1967. Now in 1975, it is represented in 24 replicated and randomized field tests, each containing many clones. These field tests are not designed to test for disease resistance, as that aspect is taken care of in the nursery. They should primarily allow us to get an idea about the growth, shape, and general health of the clones under varying conditions. Many of the tests are laid out in coastal areas, so that the clones can be tested for their exposure resistance.

In 1971, the 'Plantyn' and three other clones were up for release. Release was suspended, however, when it became clear in the same year that a different and vastly more aggressive strain of the Dutch elm disease fungus was rampant in Great Britain. Because that strain could not be expected to stay on the other side of the North Sea forever, the release of clones with an unknown degree of resistance against it would be most unwise.

Testing for resistance to the new strain was carried out in Britain, the United States, and Holland in exemplary international cooperation. Of the four candidates for release in 1971, two proved to be too susceptible to the new strain and had to be dropped.

Not without hesitation, we decided early in 1975 to release the two others to the trade, adding a third one that had not yet been considered in 1971. They were given the names 'Plantyn', 'Lobel', and 'Dodoens' (former clonal identity numbers 496, 454, and 494 respectively). Hesitations arose from the fact that even their level of resistance is no more than passable: in a few cases they have even been damaged badly by inoculation. However, they are far more resistant than

Figure 1.—Schematic development of the breeding program for the newly released elm clone 'Plantyn'.

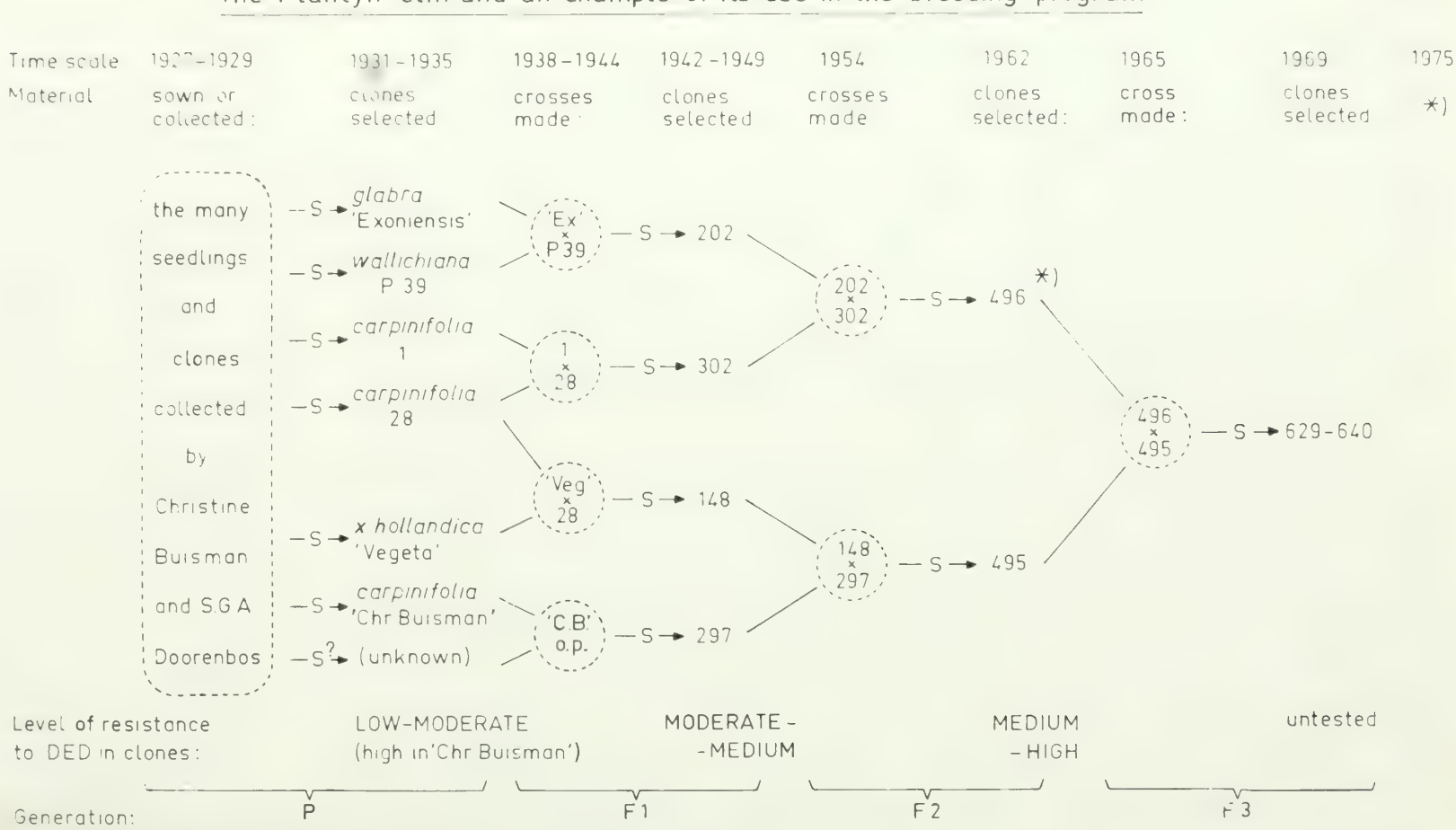


Table 2.—Properties of some old and new elm clones

| Property | Property rating by clones[1] | | | | | |
|---|---|---|---|---|---|---|
| | 'Belgica' | 'Commelin' | 'Groeneveld' | 'Plantyn' | 'Dodoens' | 'Lobel' |
| Resistance to Dutch elm disease | 5 | 4 | 3 | 3 | 3 | 3 |
| Shape | 1-3 | 2 | 2 | 2-3 | 3 | 2 |
| Growth rate | 1 | 1-2 | 4 | 2 | 2-3 | 2-3 |
| Resistance to exposure | 2 | 2 | 2-3 | 3? | 2? | 2? |

[1] Ratings: see table 1.

the widely planted 'Commelin' elm, which they can replace. They are at least as resistant as the 'Groeneveld' elm, and superior to that clone in growth rate (table 2). Though not perfect, they are considerably better than the available cultivars. The nursery trade showed much interest: 71 nurserymen applied for propagating material and had to share the 30,000 available scions. In summer 1975 again, 30,000 buds were distributed to the nurserymen for bud grafting. The trees were named after persons: Rembert Dodoens and Mathias de Lobel were medical men and botanists from the Low Countries whose famous herbals were first printed in 1554 and 1570; Christoffel Plantyn encouraged them and printed the books.

Returning to the scheme in figure 1, I wish to point out that in this example a higher level of resistance was built up step by step over two generations and in three rounds of selection. In other examples, resistant material was found right away in the P-generation after one selection step, such as was the case with the released clones 'Christine Buisman' and 'Bea Schwarz'; or similarly in the $F_1$-generation, 'Groeneveld'. Moreover, the scheme is not representative of the program as a whole in that it does not show crosses of $F_2$ clones with clones of the P-generation, and these crosses have been common. Neither does it show the use of new parent material introduced or selected after 1955.

## CLONES OR SEEDLINGS?

The Dutch breeding program, as discussed before, aims at producing clonal varieties for the trade. It can be questioned, however, whether that is wise. One can argue that massive plantings of one or two clones represent the accumulation of dangerous quantities of "fuel": just one spark, in the form of some new disease, might suffice to start an uncontrollable fire in the form of a devastating epidemic. From this viewpoint, planting clones would be preparing future catastrophies.

The Wisconsin elm-breeding program aims at producing seed-propagated elm materials (seedling varieties): for example, from the backcross *(U. pumila* x *japonica)* x *japonica.* A seedling population of elm in which less than 10 percent of the individuals are susceptible is regarded as acceptable for planting from a disease resistance point of view *(Lester and Smalley 1972; Lester 1975).*

Seedling cultivars, that is populations of seedlings, certainly have some important advantages over clonal cultivars. Since in elm apparently both approaches to improvement are feasible to some extent, and since it is the explicit aim of this meeting to discuss breeding policy, further comparison of the two approaches seems desirable. For populations of seedlings in general, four important advantages can be mentioned:

1. Seedlings tend to be cheaper than

vegetatively propagated material. This is certainly the case in elm that is rather difficult to propagate by cuttings. Nearly all of the 200,000 selected elms that are planted in Holland annually are propagated by grafting, partly on seedlings of *Ulmus glabra*, partly on rootstocks of *U.* x *hollandica* 'Belgica', which themselves are produced by layering or from softwood cuttings. The use of rootstocks may entail problems of incompatibility.

2. Clonal plants, being genetically uniform, will produce a homogeneous plantation, while seedlings will develop into a plantation that shows a certain variation from tree to tree. For landscaping and for ornamental plantings, the second type is to be preferred for visual reasons in many cases. A clonal plantation, by its uniformity, can have a more formal, more artificial air. There is some danger of monotony. A plantation of seedlings, on the other hand, blends better in the landscape and tends to be less obtrusive; it looks more natural. It contains better and poorer trees; there is variation in shape, in color and structure, in leaf size and density, in branching pattern, in time of flowering, flushing, and leaf fall. It provides more detail and interest. The effect is that more emphasis falls on the individual trees, less on the plantation as a whole. Therefore, while missing trees can spoil the effect of a clonal plantation, they do relatively little harm to a seedling plantation. These considerations may sound like the subtleties of the specialist-landscape architect, but the differences mentioned are perceived by the layman as well. In the Netherlands there is some vague opposition against planting cottonwoods these days; this may be based more on a dislike of the monotony caused by the clonal plantings than on a dislike of the species itself.

   I do not mean that there are not situations where clonal plantations are appropriate and where they will give the desired effect. In some situations, either will do. Ideally, the planter should have both clones and seedling varieties at his disposal.

3. From the standpoint of the geneticist-breeder, the replacement of populations by clones means an impoverishment of the genetic variation, and genetic variation is the basis for future breeding work. Clones like *U.* x *hollandica* 'Belgica' have been so popular in the Netherlands during the last few centuries, that there are now only a few poor remnants of the original elm population in the country. For that reason, Dr. Buisman had to introduce the elm seedlings on which she based her program from abroad, mainly from France, where a wide genetic variation can still be found in the countryside. This meant also the introduction of some more susceptibility to frost and *Nectria cinnabarina* in the materials, because France has a milder climate than the Netherlands. For a breeder, planting populations means that material for his successor is being prepared *(Koster 1974)*. It is an act of gene conservation.

4. Seedling populations, through the inherent variation in their genetic constitution, are often suggested to safeguard against future disease risks. The idea would be that some "new" disease would find not a uniformly susceptible clone, but a mixture of more or less susceptible and resistant individuals, which would at least slow down the spread of the disease. Though there may be a grain of truth in this thesis, it is not generally true. Seedlings are not *per se* more resistant than clones. When a new disorder appears, it is a question of chance as to which material will prove to be the most resistant: it could just as well be that some clones would prove resistant. Or there might be no resistance at all: chestnut blight and Dutch elm disease in North America are examples of

diseases that met practically no resistance when sweeping through perfectly native seedling populations with full genetic variation. Planters of populations should not get a false sense of security in this respect.

On the other hand, no risk-conscious plant-breeder will feel tranquil if the culture of a species rests predominantly on one or two clones. He will realize that the only, if not perfect, defense against unknown maladies is in variety: it is just a question of common sense not to put all our eggs in one basket.

If genetic diversification is the goal, each contribution is welcome: not only the variation between the seedlings of one seedling-population, but also the variation between clones. The latter can be very big in cases like elm, where species hybrids of widely different composition can qualify for use as cultivars. That means there should be many usable clones available, if possible with a divergent genetic background. It is a technical matter of secondary importance whether these clones be employed in pure groups or as a clonal mixture. It does not affect their resistance. In agricultural crops, for special diseases and under highly specified conditions, there may be cases where a balanced mixture of very special susceptible lines will behave as a resistant population *(Browning and Frey 1969)*, but this certainly does not apply to any blind mixture, and no example has been given yet in which it worked for trees.

Summing up the above discussion, I believe both clonal and seedling cultivars are welcome, though they have sometimes different roles to play. The development of seedling cultivars is certainly to be welcomed wherever the opportunity arises. The more cultivars there are, the better. The limit will be imposed by the nurseryman who does not find it profitable to carry too many cultivars.

The seedling cultivar meets a different problem in the nursery trade. To a varying extent, it is often possible to recognize the promising seedlings having the better genotype in the nursery stage; they may have a better growth, larger leaves, a different branching angle, etc. Consciously or unconsciously, the nurseryman tends to select in this material. That means that some customer will receive the poorest remaining part of the population, unless it is destroyed. For the customer now, there are few means to be sure that the plants he receives belong to the top selection or to the average, instead of to the tail end. In the Netherlands, problems of this kind occur with some other species and so far have, in practice, proved difficult to solve.

Needless to say, a tree breeder needs a certain amount of luck to find parent trees that will produce a sufficiently homogeneous and resistant offspring of sufficient cultural value. Most trees depicted in figure 1, by their hybrid nature, will give offspring that are far too heterogeneous to be of any practical value. In other words, in breeding for the development of clones, one can make use of much parent-material that is unsuitable for the development of seedling cultivars. But, as I have already said, it is worthwhile to try to find or develop parent trees that are able to produce sufficiently homogeneous seedling progenies of good genetic quality.

## VARIATION IN THE FUNGUS

Every handbook on breeding plants for disease resistance abounds with examples in which the breeder had produced a resistant variety that at a later stage turned susceptible after the fungus had apparently changed. While the variety could not be attacked by the formerly current type or types of the fungus, it proved susceptible to a new type of the same species of fungus that unexpectedly appeared. If this happens in annual crops 5 or 10 years after the new variety was released, it is serious enough; but the variety at least has produced a healthy

crop 4 to 9 times. In tree breeding, the same phenomenon would be devastating because even ornamental trees normally need 10 or more years before they really start to function, to say nothing of forest trees with their rotations of up to 100 years and more.

The theory tells us *(Van der Plank 1968)* that some cases of resistance (called vertical or specific resistance) are liable to such a breakdown caused by changes in the fungus. In another category of cases, resistance (called horizontal or general resistance) is suggested to be permanent. The difference would lie in the physiological and genetical basis of the resistance: resistances based on hypersensitivity of the host and on a single gene would normally fall in the ephemeral group; resistances based on other processes and on a multitude of genes would mostly be permanent. For a breeder, it is clearly essential to know with which kind of resistance he is working.

Elm breeders in Europe, but not those in the United States, have witnessed a serious breakdown of resistance lately. Starting in 1967, a new epidemic of Dutch elm disease has developed in Great Britain. This was something new. Although the disease had caused extensive damage between 1927 (when it was first found) and 1940, it had remained quasi-dormant since then, doing little harm *(Peace 1960)*. The new outbreak appeared to be caused by a new, much more aggressive strain of the fungus *(Gibbs and others 1972)* which was probably introduced on unbarked elm timber imported from Canada *(Brasier and Gibbs 1973)*. The new strain differs from the old type not only in aggressiveness, but also in cultural characters: on an artificial medium, it grows considerably faster, producing more aerial mycelium. This strain has now been found not only in Britain, but also in Holland, France, Germany, Italy, and Iran, while it appears to be the commonly occurring strain in North America *(Brasier and Gibbs 1975)*.

This means that the effect on breeding programs varied. For the programs in North America, nothing changed. In our Dutch program, however, we realized that we had been testing for disease resistance to a relatively weak strain, and thus had considered many elm clones to be resistant, which were in fact susceptible to the new strain. One of them, the 'Commelin' elm, had even been released and planted on a large scale: over 600,000 trees between 1960 and 1974. A complete reorientation of the program was needed, and many selections that looked promising earlier had to be discarded.

From surveying the reactions of many clones to the aggressive strain, some conclusions can be drawn. As a broad generalization, clones resistant to the weak strain exhibited a higher degree of resistance to the aggressive strain than clones that were susceptible to the weak strain. The arrival of the new strain lowered the entire level of resistance, while the ranking of clones, in broad outlines, remained the same. This was reassuring because it showed that the assembling of resistance, carried out in the program so far, had not been in vain, although the level of resistance obtained appeared to be too low. These results also were reassuring because they put the type of resistance we are working with in the category of the horizontal resistance, despite the increase in aggressiveness of the fungus. This permits us to predict that the fungus is now near the ceiling of its potential aggressiveness. In the case of horizontal resistance, the theory *(Van der Plank 1968)* does allow for some increase of aggressiveness in the parasite (though in our case the increase is unusually great). However, there is a definite limit to this increase. In vertical resistance, on the other hand, there would not be such a limit: in that pattern, each new gene for resistance can be expected to be eventually overcome by a change in the fungus.

Another possibility is, however, that the theory does not really apply to our case. Brasier and Gibbs *(1975)* suggest

that in the 1930s both the aggressive and the nonaggressive strain occurred in Europe, but that the aggressive one disappeared, only to be reintroduced from Canada recently. Now this disappearance of the aggressive strain from Europe is extremely difficult to explain in Van der Plank's theory, but reminds one of the case of *Endothia parasitica* in Europe. The latter fungus, when it was first discovered in Italy in 1938, started a severe epidemic in the forests of *Castanea sativa* in southern Europe. This epidemic slowed down after some years, however, and trees recovered. Many stands appear healthy now that were diseased earlier. The fungus is still present, but in a form that has a low aggressiveness. Like in *Ceratocystis ulmi*, strains with different levels of aggressiveness can be recognized morphologically *(Bonifacio and Turchetti 1973)*. In *E. parasitica*, there is evidence that the lower aggressiveness is associated with some contagious condition in the fungus, possibly caused by a virus *(Kessler and Elvidge 1975)*.

After inoculation of *Ceratocystis ulmi* in our clones, some variation appeared in the development of symptoms in the course of the summer *(Gibbs and others 1975)*. While clone 543 had very mild disease symptoms 8 weeks after inoculation, it rapidly developed severe symptoms in the following 6 weeks. Clone 567, on the other hand, developed severe symptoms soon after inoculation, but these did not progress any further. The two clones eventually had symptoms of about equal severity. Apparently they have slightly different types of resistance. Most other clones are intermediate in their behavior. There is a clear tendency, however, for the nonprogressing type of reaction to appear more often in Asiatic species and in some of their offspring than in other species. Also, the highest level of resistance found was in some individuals of the Asiatic species *U. japonica* and *U. pumila*. The European selections (*U.* x *hollandica* 'Vegeta', *U. carpinifolia* 1, and 28) and their offspring were, on the other hand, relatively disappointing. I conclude that the Dutch program should lean more on the Asiatic species, from which we have only a very limited sampling available. New imports, based on wider sampling, are highly desirable. Lester and Smalley *(1972)* came to a similar conclusion for the Wisconsin program.

## THE AMERICAN ELM

In the expanding literature on elm breeding in recent years, *Ulmus americana* remains in the background. This is due to several of its properties, which make it a difficult species to work with. For the breeder, *U. americana* is the really slippery elm!

First, its tetraploid nature makes it difficult to work with. A tetraploid species is more buffered against change than a diploid one. The potato breeders, who came up against the same difficulty, have been very successful in bringing their material back to a lower ploidy-level, at which rapid progress was possible. Lester *(1969)* discussed this problem and tried the same techniques for the American elm, but so far without success.

Second, the species remains extremely difficult to cross. While Santamour *(1972a)* has recently shown that many more species crosses in elm are possible than we could expect, *U. americana* still keeps separate so that it cannot profit from the progress made in the rest of the genus. A breakthrough at this point would be highly desirable. Up to now, there is only one report on an authenticated, triploid, spontaneous hybrid with American elm *(Santamour 1970)*. This tree can to some extent serve as a genetic bridge between this particular American elm hybrid and the diploid species *(Santamour 1972b)*; but, being a chance individual, the bridge seems too narrow to be of general use. It should be possible to find a way to produce hybrids at will, perhaps by using irradiated pollen, tetraploidized forms of diploid species and hybrids, embryo culture, or other methods.

Third, the few seedlings remaining from mass-screening for resistance in American elm at different stations have provided a very unpleasant surprise. These individuals have survived many artificial and often also natural inoculations and could thus be regarded as being resistant to a considerable degree. Quite unexpectedly, however, ramets of most of these trees in the form of cuttings or grafts proved susceptible *(Sinclair and others 1974; Lester and Smalley 1972)*. As yet, this effect is unexplained. There was just a minor effect in favor of the selected clones: if inoculations were carried out after the seasonal peak of susceptibility, selected clones showed less symptoms than unselected standards. Both publications further report that seedlings from crosses between those selected trees were hardly less susceptible than unselected seedlings. Resistance is not entirely absent in American elm: Townsend and Schreiber *(1975)* report on a resistant clone.

Fourth, the recent extension of the known range of phloem necrosis to the Northeast *(Sinclair and Filer 1974)* has been another disappointment for those who had hoped to see a resistant and widely usable selection of *U. americana* in the near future. In large parts of the species' area, a new American elm would perhaps need resistance to both Dutch elm disease and phloem necrosis, unless a reasonable control method for the latter disease can be found.

In view of the many difficulties posed by the American elm, one might suggest dropping that species and developing other elms instead with a shape similar to that of the "typical" American elm. Such a goal seems quite attainable by breeding. The commonly occurring spontaneous hybrids between red and Siberian elm sometimes come close to it; they only lack in resistance to the disease. This could be improved by breeding with other diploid elms of a more or less similar shape as *U. laciniata, U. laciniata nikkoensis, U. japonica, U. wallichiana, U.* x *hollandica* 'Vegeta', *U. bergmanniana* and others *(Heybroek 1968, 1969)*. This approach looks promising.

However, one would not like to drop the American elm entirely. It seems that some major research efforts are needed to get the development of good and resistant cultivars of American elm effectively on the way. The importance of breaking the incompatibility barrier has been mentioned earlier *(Heybroek 1968, 1969)*. It would further be desirable to know whether the anatomical markers for disease resistance *(Sinclair and others 1972; McNabb and others 1970)* in the resistant selected seedlings are different from those in their susceptible vegetative reproductions, and also to what extent these markers can be used in a large-scale screening program on full-grown trees. In addition, a survey of the species' variability (morphological, physiological) over its entire area would seem a most valuable basis for a rational breeding effort, for instance it might locate centres of diversity.

## CONCLUSION

There is not just one single prescribed breeding policy for elms. In reviewing desirabilities and attainabilities, it appears that different courses can be followed to produce better elms, each course with its specific advantages and limitations. It is the breeders' responsibility to determine which options are best suited for his conditions.

If the available options seem too meagre, as is the case in American elm, more or less basic research is needed to open up new options. The import of new gene material can likewise increase the possibilities for developing various safe and valuable clonal, or perhaps even seedling, cultivars.

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# PERSPECTIVES ON IMPROVEMENT STRATEGIES FOR METROPOLITAN TREES

*by* FRANK S. SANTAMOUR, JR., *Research Geneticist, U.S. National Arboretum, Washington, D.C.*

*ABSTRACT.* The goals of tree improvement may vary considerably, depending on the genus or species under study. Maximum improvement can be achieved only by an adequate knowledge of the variability present in the gene pool, whether the pool is restricted to a single species or all species of a fairly large genus. Bizarre or atypical trees, although often regarded as ornamental, cannot be considered as significant goals of a scientific breeding and selection program. On the other hand, trees that produce no fruit or seed may be highly desirable in a metropolitan environment.

IT SHOULD BE painfully obvious to those attending this Symposium and to the readers of these Proceedings that we have barely scratched the surface of possibilities for metropolitan tree improvement. Papers have been given on selection strategies in elms *(Ulmus)* and maples *(Acer)*. This presentation should, then, deal with the hundred or so other genera grown and used as landscape trees in temperate zone of the United States.

It should be joyfully obvious that there are real opportunities for significant improvements in genera virtually untouched by research. The choice of plant materials and objectives will vary among scientists, depending on their backgrounds, present research situation, and any restrictions imposed upon them.

I will touch upon some of the problems and prospects of improvement research in the other genera, using, when appropriate, examples of work under way or contemplated for the 50 genera being studied by our project at the U.S. National Arboretum.

No attempt will be made to point out the importance of pest resistance or tolerance of urban environmental stress factors. Cold hardiness potentials will be dictated by the seed origins available. Proper evaluation and testing procedures are necessary in all genera. These are lessons that have been presented before.

## MONOTYPES

About 20 of the 50 genera being studied at the National Arboretum are biological or cultural monotypes. The classical biological monotype in trees is *Ginkgo biloba*, of which only a single species exists. Others may include *Eucommia ulmoides*, *Idesia polycarpa*, *Oxydendrum arboreum*, and *Kalopanax pictus*. Taxonomic "splitters" may have described varieties or

other species in *Ailanthus* or *Cercidiphyllum*, but the best known species are essentially monotypes. Our imperfect knowledge of the intraspecific variability in these species' gene pools makes a definitive statement of improvement prospects impossible for some genera.

As cultural monotypes I would include genera in which a single species accounts for 95 percent of the types currently grown and used in the nursery trade. In some genera, the non-native species are little known, and our single native species of *Liquidambar* and *Liriodendron* are really cultural monotypes. In *Gleditsia*, some 10 to 12 species are cultivated in arboreta throughout the world, but in the United States *G. triacanthos* is the only species grown commercially in any numbers. Cold-hardiness may be a limiting factor in reducing to one the available species in tropical genera like *Paulownia* and *Albizia*. Other genera, such as *Sophora* and possibly *Robinia*, have only one hardy tree-type species. Although a wider range of plants can be grown in Florida, the Gulf Coast, or California, the scientist should probably aim for a greater range of adaptability for his superior products.

True biological monotypes generally present few serious pest problems. The fact that they have existed in nature for geological periods with a restricted gene pool is testimony to this status. Again, the tree that first comes to mind in this regard is *Ginkgo*; but there are others, like *Maclura* and *Eucommia*. The wide adaptability of *Ginkgo* may mislead us into thinking that monotypes also present few, if any, cultural problems. Of two native American monotypes, *Franklinia alatamaha* has disappeared in the wild, and *Elliottia racemosa* is now consciously being saved from extinction in its native habitat. Both of these species are difficult to maintain in optimum condition under cultivation.

Cultural monotypes may have no advantage in pest resistance. The American chestnut *(Castanea dentata)* could be considered as a sort of cultural monotype. The story of the chestnut blight is well known. Honeylocust *(Gleditsia triacanthos)* was thought to have few serious biological problems until the introduction of the mimosa webworm. Who can say, with certainty, that *Liriodendron tulipifera* might not become the victim of an introduced disease or insect pest that once preyed on *L. chinense*.

In working with biological monotypes, it is important for the scientist to sample and define the degree of variability present in the species. Seed collections from native stands throughout the species range would be ideal, but there may be problems with certain Asiatic species. Failing that, seed and plant collections could be made from earlier plant introductions of diverse known origin. Any collection scheme that is possible and workable is appropriate in the early phases of a research project. Even if a species may be represented by only one or a few mature trees in cultivation, some meaningful assessments of the species' potential can be made.

For cultural monotypes, every effort should be expended toward the collection of other species in the genus, even if the literature indicates that certain species have few good horticultural attributes or are not hardy in a particular climatic zone. For instance, we are growing 12 species of *Gleditsia*, from such diverse origins as Argentina and Hong Kong, to determine their susceptibility to mimosa webworm. Only by these tests can we ascertain whether resistance breeding programs have a chance of success. We have also grown *Albizia* species from tropical Africa and the Pacific. For years we have attempted, unsuccessfully, to bring the rare *Platanus kerrii* from Laos into cultivation. Any genetic or cultural data on species related to cultural monotypes will allow the scientist to develop a breadth of understanding that would be impossible when working with only a single species.

## SPECIES VERSUS GENERIC IMPROVEMENT

Much is written about species improvement, but frequently the phrase is improperly used or misapplied. The basic unit of tree improvement is not the species, but the genus—or at least those members of the genus with which the principal species is cross-compatible. I should mention that this concept has long been preached by Ernst J. Schreiner, the dean of American forest genetics.

Of course, improvement in biological monotypes must be restricted to a single species. With many cultural monotypes, the superior adaptability of the principal species or the nonavailability of related species may so restrict our thinking that we neglect the possibilities of interspecific hybridization. Frequently, the main impetus for a broader multispecies breeding pool is the occurrence of a major disease epidemic or insect infestation. Then we attempt to make up for past neglect by experiments that could have been carried out a decade ago, and from which the answers to certain questions would be at hand.

Thus, the determination of the crossability patterns of our major species, whether called "reconnaisance breeding" or the "shotgun approach", is both scientifically and practically sound. There are two major products of tree-improvement research: knowledge and better trees. We, as scientists, have a certain amount of control over the knowledge aspect, and any experiment is better than none at all. We have far less control over the ultimate use of the improved trees that we produce. Any increase in our knowledge of trees must be considered worthwhile; and if we can someday drive down an avenue of trees that we developed, so much the better.

In some genera, the breeding pool may include *all* species of the genus. This is especially true in certain small genera like *Liquidambar*, *Lirodendron*, and possibly *Platanus*. In larger genera, for which taxonomists have erected subgeneric, sectional, and series categories, the crossability patterns tend to reflect the classification. The scientist should appreciate, but not be restricted by, taxonomic classes. In *Magnolia*, many intersectional crosses have been accomplished and, recently, even the subgeneric boundary has been breached. We might find that controlled interclass hybrids are also possible in *Quercus*, *Acer*, *Cornus*, and *Fraxinus* if enough attempts are made. It is remarkable that more natural or garden-origin interspecific hybrids have been described in *Tilia* than there are species in the genus. Yet, to my knowledge, no real breeding effort is being expended on the lindens.

So there is still much to be learned about species crossabilities; and the wider the gene pool at our disposal, the greater will be our chances of producing truly superior trees.

## CONIFERS

We had originally intended to include a paper on conifer breeding in this Symposium. Several prospective speakers were asked, including an eminent forest geneticist from the Far West. His "paper" is quoted below in its entirety, anonymously, with his permission:

> You do experiments for other purposes, but keep your eyes open. When you see an interesting plant, which will generally occur in an unexpected place, you grab it and test it.

While there is an element of jest in the above statement, it describes rather well the current thinking about the state of the art. Most, if not all, conifer genetics research in this country is conducted in forestry-oriented institutions by forestry-trained scientists. The major goals of their improvement programs are increased growth rate, improved wood quality, and pest resistance. Some attention is also being given to pollution tolerance and drought resistance. Provenance testing, for the selection of the best geographic seed source for various climatic situations, has long been a major part of

conifer improvement research. The goals of forest tree improvement are thus not totally incompatible with those of metropolitan tree improvement.

Of course the conifers of forestry are mostly pines, while those of horticulture have traditionally been *Juniperus, Thuja, Chamaecyparis,* and the like. Except in the South and on the West Coast, pines are seldom a major urban landscape item. However, in the Northeast, the use of our native eastern white pine *(Pinus strobus)* along highways has increased to the point where the species might be considered overplanted. Certainly, the known sensitivity of this species to air pollutants should prompt a change or the selection and propagation of tolerant types. If progeny tests indicate good heritability of pollution tolerance, seed orchards could be developed to produce an improved seed-propagated cultivar.

As urban forests and greenbelts become more common, we can use the best products of forestry-oriented improvement research on conifers. Whatever the shape, color or growth rate of those trees destined for metropolitan usage, adequate long-term tests of adaptability will be necessary.

## FREAKS AND FADS

Also implied in the above-quoted "paper" on conifers was the idea that the interesting plant should be different. The more different the better, according to some persons. This concept did not originate with foresters. Anyone looking at the abundance of dwarf, contorted, creeping, crawling, weeping, yellow-needled, variegated, and otherwise atypical conifer cultivars in nurseries or arboreta would have to conclude that these were plants to be desired. A forest geneticist who found a freak in his provenance or progeny test was sure that such a plant would have horticultural merit.

My own personal opinion is that freak plants should not be considered as goals of breeding. There is no desperate need for more bizarre plants. If they do occur, as byproducts of a research project, the scientist should seek the guidance and counsel of experienced nurserymen and landscape architects to determine if the exploitation of this plant would do any more then add another name to the ever-growing list of seldom-cultivated cultivars.

The possibilities of miscalculation about the merits of freak plants are particularly apparent in conifer breeding. With broad-leaved deciduous trees, the runts are promptly discarded and forgotten. A landscape niche that might be filled by a dwarf elm could better use a normal plant of a different genus, which would, more often than not, present a more pleasing aspect through the years.

The use of weeping trees grafted high on standards is, like pollarded catalpas, a fad that waxes and wanes in popularity. Trees with variegated foliage may be beautiful or pitiful, depending on where and how they are grown. Over most of the 48 contiguous states, the long, hot summers render many variegated trees unsightly in comparison to the same cultivars grown under a cool and moist environment. The development of red-leaved trees may offer more room for improvement and demand more skill on the part of the scientist.

In summary, I would suggest that the geneticist resist once, and maybe twice, the urge to make a cultivar of that strange bud sport or weird seedling. If, after due consideration, he cannot help himself, there may be little harm done.

## FRUITLESSNESS

Most trees produce fruit that, at certain times and in certain places, could be considered objectionable. The fruit of some trees is far worse and more universally unloved then others. Heading the list is *Ginkgo biloba.* But ginkgo is dioecious, and the selection and propagation of male trees easily overcomes the potential problems. Other dioecious trees include

certain ash *(Fraxinus)* species, *Nyssa, Ailanthus, Maclura, Morus,* and, functionally, red maple *(Acer rubrum)*. Problems caused by tree fruits are easily solved in dioecious genera and species and, barring any rare sex-linked desirable characters, the male trees can be just as good as the females.

In some trees, such as *Aesculus, Gymnocladus, Liquidambar, Quercus, Sophora,* and even *Tilia,* the fruit itself may constitute a nuisance or hazard in areas of intense pedestrian traffic. The main objection to fruiting in other trees, like the spring-fruiting elms and maples, *Albizia, Robinia,* and *Paulownia,* is the ubiquitous presence of unwanted seedlings in lawns, garden plots, planters, walkways, and other conceivable and inconceivable places.

In this connection, we should remember the very real differences between self-incompatibility, sterility, and fruitlessness. Most conifers and certain deciduous genera like *Liriodendron, Liquidambar,* and *Platanus* are highly self-incompatible, but they are also strongly parthenocarpic. Thus, although few if any viable seeds are produced from self-pollination, the abundance of fruit is not significantly diminished. Fruiting in the 'Bradford' pear is not a problem where that is the only cultivar being grown; but the near presence of other cultivars or seedlings of *Pyrus calleryana,* which may be compatible with 'Bradford', may alter the fruiting pattern.

Sterility refers to the nonproduction of viable gametes, usually as a result of meiotic irregularities. Such irregularities may often occur in interspecific hybrids. However, natural or artificial tree hybrids between species at the same level of ploidy may be fertile; and even if viable seeds are not produced, they may be parthenocarpic and produce fruit. One outstanding example of interspecific hybrid sterility at the diploid level is the original clone of *Magnolia* x *thompsoniana (M. virginiana* x *tripetala),* which has not been known to produce a mature fruit since its origin in 1808. Hybrids in most trees, however, are not sterile, and even if partially sterile, are not fruitless.

Meiotic irregularities arising from triploidy may also result in sterility and fruitlessness. The naturally occuring triploid aspens *(Populus tremuloides)* and the many triploid cultivars of apple *(Malus)* are, however, quite fruitful. When triploidy has occurred through interspecific hybridization between a tetraploid and a diploid species, sterility may or may not result. The triploid progeny from the cross of the tetraploid *Magnolia liliflora* with the diploid *M. stellata* (some 50 plants) have not produced a single mature fruit in 10 years of flowering. On the other hand, triploid hybrid birches *(Betula)* may produce abundant fruit and viable seed. The use of this approach to fruitlessness is restricted to genera having a polyploid series of compatible species. Sterile triploids may be possible in *Fraxinus, Carya,* and *Tilia.* In *Aesculus,* we have produced triploid hybrids from crosses of diploid species with the hybrid tetraploid (amphidiploid) *A.* x *carnea.*

Another method of achieving the triploid, sterile, and fruitless condition is by crossing colchicine-induced tertaploids with normal diploids of the same species. Judging by breeding experience in other plants, we could expect some successes and some failures. It might be expected that a triploid *Liquidambar styraciflua* would be sterile, but not fruitless. However, the possibilities of this approach seem so promising that we are attempting such work with a number of flowering trees, including *Albizia, Catalpa, Paulownia,* and *Sophora.*

Fruitlessness may also be caused by "doubleness" of flowers or be "created" by the selection and propagation of branches of monoecious trees that produce only male flowers. Regardless of its cause, or the preferences or intentions of the geneticist, the lack of fruit and seed can be highly desirable characteristics.

## SELECTION SEQUENCE

Those characteristics that are the *limiting* factors in the utilization of a tree must be stressed in the initial phases of selection. If there are several important factors, some priority ranking must be assigned to those factors, and the screening process can be designed to shorten the duration of the testing period.

In breeding for tree-type magnolias at the National Arboretum, growth rate and habit are, naturally, of prime importance. However, magnolias are flowering trees, and the presence of attractive flowers and their abundance will be the key elements in the tree's popularity. Fortunately, in the 7 to 15 years required for a magnolia seedling to flower, some very good assessments of growth performance can be made. After flowering for several seasons, some trees with outstanding growth characteristics may have to be discarded. Since magnolias have few serious pests, any further screening to encourage wider use of the potential cultivar should involve tolerance of air pollutants or salty and compacted soil.

Where a disease is the limiting factor, and artificial inoculation procedures for young seedlings have been developed, the geneticist can indulge in severe mass-screening procedures. Resistance to secondary pests and tolerance of environmental stresses may then be determined on a small, selected population.

Verticillium wilt in green ash *(Fraxinus pennsylvanica)* may not be considered as a true limiting factor, since the planting of ash has not been deterred by our lack of knowledge about resistance. Still, ash is known to be highly susceptible to Verticillium. Since there are already male cultivars having desirable growth characteristics and good full color, the next logical step in improvement is the production of disease-resistant cultivars, or rootstocks. Among insect pests, certain borers may be real problems, and some further testing of the disease-resistant population could be made. And what about the flower-gall mite, which can make a male white ash *(F. americana)* less than a thing of beauty?

Screening for insect resistance is far less reliable than screening for disease resistance, because during periods of peak insect populations, even some non-host species may be attacked. Any tree-improvement project worthy of the name must determine, at least, the *relative* resistance of their selections. Some attention must be paid to borers in birch *(Betula)* and dogwood *(Cornus)*, mimosa webworm on honeylocust *(Gleditsia)* and mimosa *(Albizia)*, leaf miners in birch and black locust *(Robinia)*, and even Japanese beetle on practically everything.

A number of insect and disease pests are known to cause problems in the lindens *(Tilia)*, but seldom warrant control measures. What is known about certain linden species, however, is that they are extremely intolerant of poor soil aeration and salt in the soil. Improvement procedures for the development of superior cultivars (or rootstocks) in *Tilia* should begin with mass screening against these environmental stresses.

The development of improvement strategies for each tree species or genus will depend on the availability of plant material, and the facilities, equipment, experience, and opinions of the scientist. No approach is inherently wrong or right, but *some* approach is necessary.

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# SOME APPROACHES TO COLLECTING ORNAMENTAL TREES AND SHRUBS

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*ABSTRACT.* The author discusses some of the potential benefits from collecting seed of trees and shrubs from their native habitats, and the role of arboreta in providing seed material to plant breeders as well as maintaining genetic resources. Some observations are made on methods of field work.

WE LIVE IN A TIME when great concern is being expressed over the loss of wild plants, ranging from the progenitors of crop plants to endangered species in habitats that are being eliminated through the encroachment of civilization on natural areas. In most localities, noneconomic woody plants are the first to go—though they often have some interim use as firewood, fence material, or some other practical value when land is cleared or grazed.

This is also an age when there is not only a world-wide interest in "greening up" cities, but also awareness of the impact of pollution, high-intensity street-lighting systems, restrictions on certain pesticides in urban areas, and several other environmental factors on our street trees. Most of these factors are being discussed during this Symposium.

The exploration for and introduction of species and cultivars from both domestic and foreign sources are basic to the selected strategies being proposed to meet the needs of breeders. The question raised by the need for a diversity of genetic material in view of the continual demise of woody-plant resources is whether we may soon be short of available plant materials.

## COLLECTING GERM PLASM

Available resources can be wild species collected from localities throughout their natural distribution, or as an alternative, specimens growing in botanical gardens in those countries where the species are native. Cultivars can be introduced from foreign botanical gardens, nurseries, experiment stations, and private gardens. In many instances quarantine regulations make the movement of vegetatively propagated selections quite difficult. In general, a broad array of documented seed from natural areas is the best source of breeding material, provided the breeder can afford to be patient.

Since colonial times, we have introduced trees and shrubs into cultivation, either our native species or those from

foreign countries. The history of our efforts to introduce useful ornamental species has been well documented *(Manks 1967)*.

The search for new plants has been guided by our needs to improve the urban and rural environment. The many introductions of the Siberian elm *(Ulmus pumila)* from China and Siberia were intended for windbreaks and shade trees in the cold dry regions of the north-central United States. The goal was to find trees from the inner regions of Asia that would be suitable to a similar climate in the United States. This search was not related to the subsequent use of the same species in research to develop resistance to Dutch elm disease. Yet the information accumulated as a result of the early introduction programs with *U. pumila* and other Asiatic elms has been most valuable in the current research effort.

The U. S. Department of Agriculture collected *Castanea mollissima* and *C. crenata* from 1927 to 1931 in China and Japan as sources of resistance to chestnut blight. The disease had spread from Asia to the United States, where it devastated our native stands of chestnut *(C. dentata)*. The goal of collecting was to gather large quantities of seed from the regions where the fungus and the most resistant species occurred together.

Finally, there are instances in which trees were introduced for one purpose but made their fame in a different manner. *Pyrus calleryana* was introduced in the early 1900s in hopes that its resistance to fire blight *(Erwinia amylovora)* could be transferred to the common pear. It failed in this way, but it became useful as an understock and then later as an ornamental street tree. *Pyrus calleryana* might not have achieved this ornamental status had there not been the economic emphasis that required an intensive seed-collecting effort.

Most of the introduced plants cultivated in the United States are, to a great degree, cultivated in the lands where they are native. These have been secured through the activities of botanists, professional plant collectors, and lay people of many persuasions, ranging from priests, doctors, government officials, and nurserymen to amateur gardeners.

In our contemporary plant-collecting activities, the cooperative program initiated in 1956 between Longwood Gardens, at Kennett Square, Pennsylvania, and the Agricultural Research Service has been the most successful and sustained effort. It has supported 13 explorations for ornamental trees, shrubs, and herbaceous plants for both garden and conservatory. This program, we hope will continue for some time, because there are many fertile areas still to be explored.

The PL-480 grant program sponsored by the Department of Agriculture is one post-World War II source of trees and shrubs that has not been so prominent. These in-country funding programs are near termination in regions of interest to us. However, one PL-480 project that has been successful is the collecting of native trees, shrubs, and other ornamental plants of west-central Yugoslavia. The collecting work, done by the Biological Institute at Dubrovnic, has resulted in about 285 lots of seed sent to the United States. The value of this effort is that there has been a sustained collecting activity over several years. This has resulted in a much broader array of variants of any given species than could be gathered by a single collector in one season. Unfortunately, the distribution of PL-480 funds has not necessarily coincided with the countries where there is a broad array of temperate woody species.

In addition to these cooperative programs, the National Arboretum sponsors a program of collecting native ornamentals of Appalachia in cooperation with West Virginia University. This program, now in its third 2-year grant period, emphasizes the collection, distribution, and conservation of native hollies, azaleas, hemlocks, and other species that will be of promise in the nursery trade. There is much in common between this kind of

domestic grant program and the PL-480 projects described above. It utilizes local expertise on a sustained basis and brings valuable germ plasm into cultivation without endangering wild species.

The exchange lists from botanical gardens and arboreta are another means of obtaining genetic resources. These lists have had a poor image in recent years because some of the material tested has been found to be of questionable parental identity. More recently, arboreta have begun to provide seed of native species collected in the wild and documented with herbarium specimens to support identification. If this trend continues, seed lists may become of greater importance to plant breeders. This is especially true as more nations restrict the collecting of wild plants by foreigners except in close collaboration with local institutions.

My own experience in field-collecting over the past 20 years has been marked by a shift from rather free access to a country to a scheduled march-route sanctioned by the host country and its plant organization. Though this might have discouraged the early plant collectors, it is decidedly advantageous in terms of transportation and shipment of collections. Furthermore, it allows for follow-up collecting by the local people who accompany the foreign collector.

## MAKING GERM PLASM AVAILABLE

The increase and evaluation of woody species are still developing and in need of additional improvement. We have not solved the problem of adequate distribution and evaluation of tree and shrub introductions so as to meet the needs of breeders and, at the same time, conduct objective evaluations for purposes of adaptation.

The common practice in handling introduced woody-plant seed is to germinate the entire lot and then distribute seedlings widely. The other alternative is to raise the seedlings at the home institution, line them out in the nursery, and eventually select from them or use them in breeding. Obviously, both procedures have their merits and shortcomings. The National Arboretum and the Glenn Dale Plant Introduction Station attempt a combined operation because they have both breeding programs and a broad distribution program. When seeds are received from a foreign source, they are sown immediately. The resulting seedlings are destined for three purposes: (1) to provide trees and shrubs representative of the wild species for our permanent collections; (2) to provide the research staff with new materials for their breeding and evaluation programs; and (3) through the remaining seedlings and an offer in our domestic distribution list, to establish the new materials at other botanic gardens and arboreta.

This procedure permits us to use introductions to best advantage. We presume that there will be close cooperation between breeders working on the same genus. The plant breeder must rely on arboreta as sources of parental material. There is no question but that arboreta are and will be the main repositories for the germ plasm of woody ornamental plants. Therefore, these institutions have a responsibility to see that the specimens assembled in their collections include a sufficient array of documented wild materials to benefit breeders of the future. It is very discouraging for the plant collector to introduce a species from its native habitat only to find that the representative plant in a major collection is one obtained from a foreign source without proper documentation of origin. If the long-range needs of breeders and other users of these genetic resources are to be considered, arboreta must plant specimens with proper documentation.

The Germ Plasm Resources Laboratory at Beltsville, Maryland, has the basic responsibility for plant introduction. In addition to the National Arboretum, four regional introduction stations—at Ge-

neva, N.Y., Ames, Iowa, Experiment, Ga., and Pullman, Wash.—and the ARS research stations at Glenn Dale, Md., Savannah, Ga., and Miami, Fla., collect and distribute plant materials. The four regional stations also have undertaken a sustained program of more than 40 domestic explorations. Ten of these have been for collecting ornamental plants *(Burgess 1971)*. These collections are sent to one or more state experiment stations, which agree to maintain the germ plasm for use by breeders and other scientists.

## SOME TACTICS OF PLANT COLLECTING

I have suggested that seed lots collected in native habitats offer breeders an opportunity to improve on existing shade trees. Sufficient variation exists among trees and shrubs to encourage greater use of seed collections. This variation has been used to a limited extent, selecting within a seed sample and through comparative evaluation among seed lots from different geographic sources. In Japan, geographic races of *Cryptomeria japonica* from the moist, snowy regions along the Japan sea perform differently in winter survival than do those collected along the Pacific Ocean side of Honshu where the winters are dry and sunny. Seed progenies of *Pinus densiflora* collected from south to north in Japan show marked differences in winter injury when grown together on the northern island of Hokkaido. *Zelkova serrata* populations from several sources in Korea have behaved differently when grown in nursery rows in New Jersey, but with a uniform growth character within each sample.

The availability of geographic and ecological strains of trees and shrubs offers great possibilities, in lieu of vegetatively propagated selections. The genetic variation may be of significance in relation to resistance to insects and diseases, horticultural traits, and adaptation in comparison to vegetatively propagated cultivars.

Several years ago (1961), I collected seeds of *Rhododendron japonicum* from the southernmost colonies in Kyushu, Japan, to the northernmost stands at Mt. Hakkoda, Honshu. The southern colonies contained plants with either yellow or orange flowers. As one travels northward, fewer yellow-flowered plants can be found. At the northernmost stand, the flowers are uniformly orange. It can be presumed that there is a relationship between flower color and hardiness. In China, there is a closely related species, *R. molle*. It is entirely yellow-flowered and is considered to be less hardy than *R. japonicum*. Dr. W. L. Ackerman of the National Arboretum is studying these Japanese seed collections to develop true-breeding lines as a means of providing nurserymen with color forms reproducible by seed. The same use has been made of seedling progenies of the Japanese maple *(Acer palmatum)*, of which red-leaved forms have been successfully raised from seed by nurserymen.

There are undoubtedly additional examples of species in which seedlings are or should be grown in preference to clonally propagated selections. This technique is worth considerably more attention as we face additional economic limitations in plant production. Furthermore, many species are difficult to propagate vegetatively. Selected seed lines are far more appropriate than the unselected seedling material being planted in some areas as an alternative to clonal selections.

The quarantine aspect of plant introduction is an essential safeguard against inadvertently introducing new insects, diseases, and weeds. In general, most quarantine regulations are based on the risk factor. For example, seeds rather than vegetative material should be introduced when possible. For clonal propagations, unrooted material should take preference over rooted plants, and woody

plants should not be more than 2 years old.

The greatest concerns are viruses, which are not readily detected by visual observation. Some viruses are symptomless, and detection requires a complex indexing technique. As a result, most governments have very stringent regulations about importating vegetative stocks of certain genera. In the United States, it is necessary to obtain permission from the Plant Protection and Quarantine Programs Unit, Animal and Plant Health Inspection Service, Federal Building, Hyattsville, Md. 20782, before vegetative stocks or seed of woody plants can be imported.

## BASIC AIDS TO FIELD COLLECTING

The methods of field collecting vary widely according to the objectives and nature of plant materials. While collecting of economic crops is often associated with areas of primitive agriculture, the search for germ plasm of woody ornamental trees and shrubs is more often carried on in natural sites remote from civilization. As a consequence, breeders have been dealing with a rather narrow base of germ plasm, and selections of shade trees have been made from single-seed collections made in the wild, but more often, from specimens in botanical gardens. This problem stems from the limitations placed on field collectors for making repeat visits to a foreign country. Sustained collecting is essential to achieving a broad base of germ plasm.

When species with good prospects have been determined, familiarity with the total range of distribution of the species is important. The various manuals of cultivated plants provide a key to describe species and their country of origin. Bailey's *Manual of Cultivated Trees and Shrubs* is essential. Local and regional floras *(Ohwi 1965)* are important resources in determining species to be collected. In addition, plant distribution maps *(Hara and Kanai 1958)* are extremely valuable in relating travel plans to distribution range of species. Though some of these maps are published, many others are available through personal contacts with local botanists. Finally, the agro-climatic analogs prepared by Nuttonson *(1951)* have been most useful in predicting the degree of adaption one might expect from collections.

There are many additional sources of information that are basic to field collecting. Perhaps most important is a working relationship with competent local botanists, horticulturists, and foresters. It is best to establish a single main contact in a foreign country. Then, allow him to make the local contacts according to a schedule established to meet the objectives. Obviously such logistical details as country clearance, collecting permits, transportation, shipment of supplies, and return shipment of collections, including quarantine permits, have to be completed well in advance.

In an initial visit to a country (like Japan) that is rich in woody plants, both wild and cultivated, the collector is first inclined to gather everything. But on subsequent journeys, concentration on collecting a few important species throughout their entire range of distribution is more productive. In such collecting, one must plan the trip according to the advance of the seasons; i.e., south to north, and lower elevations to higher ones in the case of flowering. In certain climates, such as the warm southern islands of Japan, seed collecting can be undertaken during the entire winter. In other areas, seed collecting is limited strictly by the approach of winter. There is no single optimum time to be in the field. That is why the early collectors, forced by surface transportation to spend periods of 2 to 3 years in the field, had some advantage over modern collectors. The latter may limit their journeys to a few months according to flowering or seeding seasons.

The collector, once having elected to

emphasize certain genera or species, must plan his schedule according to the advance of the season. For example, in collecting *Rhododendron kaempferi* in Japan, I followed the flowering season from early May in Kyushu to early July at the northernmost limit in Hokkaido. Similarly, I was able to follow the pattern of distribution of *Camellia japonica* from Okinawa to the northern tip of Honshu, where the last colony is to be found. In terms of elevation, it was possible for me to collect *Rhododendron pseudochrysanthum* at elevations from about 9,000 feet to 14,000 feet on Mt. Morrison, Taiwan. In this instance, I made an effort to gather seed at about 500-foot changes in elevation. As mentioned earlier, we were able to obtain seed of *Cryptomeria japonica* from four distinct climatic regions in anticipation of differences in performance. These are a few examples of opportunities that are open to collectors who are intent on providing a good sampling of a species.

Lacking the opportunity for actual collecting, breeders can always request the help of foreign botanic gardens and arboreta. They may be willing to collect native species at a nominal fee. In either case, the success of tree improvement through selection will depend on our ability to acquire a diversity of germ plasm. Otherwise, only a limited degree of progress can be expected.

## CONCLUSIONS

Many opportunities exist for obtaining resources for the improvement of trees and shrubs. Collections of seed gathered from native habitats can provide breeders with sources of disease and insect resistance, improved horticultural traits, and better adaptation. Although direct collecting in the wild is the best approach, breeders should not overlook seedlists of arboreta and botanic gardens that emphasize species documented as to origin. Ultimately, seed strains of shade and street trees with acceptable quality may become a standard source of plant material for urban plantings. In the meanwhile, we will need to improve our methods of distribution and evaluation of germ plasm of trees and shrubs to make this material available widely. The arboreta and botanic gardens that maintain the genetic resources developed through such research programs will become a major resource for future plant breeders.

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# TESTING AND EVALUATING NEW TREES FOR METROPOLITAN LANDSCAPES

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*ABSTRACT.* In the landscape-tree industry, genetic variation among species, clones, and other genetic units is most commonly exploited for improvements in appearance traits. The relatively little known of genetic differences in performance traits comes from the personal experiences of arborists and horticulturists. Further genetic improvements in the ability of trees to survive in urban environments require the use of systematic and statistically sound procedures of testing and evaluation. Some fundamental principles of testing and evaluation are reviewed. If selections are to be used in urban localities, it is important that they be tested in those situations, unless clone-environment interaction is likely to be small for the traits, trees, and sites in question. A plan is outlined for coordination of the respective activities of research institution, nurseryman, and arborist in establishing test plantations.

ARBORISTS, CITY FORESTERS, landscape architects, and nurserymen all utilize genetic variation among trees. Differences among genera, species, and cultivars impart variety to the landscape and constitute the basis for recommending one tree over another. Successfully exploiting this variation to select better trees for metropolitan landscapes requires, of course, that genetic superiority first be recognized. How to do this correctly and efficiently is a question that demands exploration as we attempt to adapt scientific methods to the improvement of trees for urban environments. Some procedures can be drawn from experiences in forest-tree improvement; but many problems in urban-tree improvement require answers that cannot be borrowed from other disciplines.

Recognizing genetic superiority requires two steps: testing (deliberately exposing trees to an appropriate environment) and evaluation (measuring genetic differences in quality of appearance or performance). We will deal here with testing and evaluation in their more formal modes—where these activities are

distinct and deliberately planned phases of the tree-improvement program.

But we do not mean to imply that testing and evaluation are necessarily new or complicated procedures. Anyone who plants a tree is testing it in that environment; and he will eventually evaluate the results according to the tree's appearance or survival. The usefulness of this technique is revealed by the availability of numerous lists of species appropriate for different uses and regions—all compiled without resort to formal procedures of testing and evaluation.

In fact, the sophistication of procedures needed in testing and evaluation may vary, depending upon (1) the traits being measured and (2) the degree of genetic variation among the trees being tested. Selection among species, for example, is relatively easy because the large genetic differences in traits usually eclipse the effects of environment on their expression. Knowledge gained through trial-and-error on the suitability of different species is usually very sound. Similarly, genetic variation in traits that are stable over a wide range of environments is also easy to measure without complicated experiments. Traits that fall in this category are usually related to *appearance*: flower color and size, branching habit, leaf shape, etc. Testing in such cases may be coincident with the necessary process of raising the plant material, and evaluation may be reduced to the simple recognition of unusual trees.

The situation is different when genetic variation is small (intra- rather than interspecific) or traits are heavily influenced by environment (often *performance* traits like growth rate and disease susceptibility). When this is true, testing and evaluation may require statistically designed and analyzed experiments performed in controlled or selected environments. Until recently such procedures have not been as necessary as they are now, or at least they have been avoided. As we become more concerned with intraspecific variation in performance traits of urban trees, it is important that we begin with sound principles and procedures of testing and evaluation in mind.

In the following sections we review some fundamentals of testing and evaluation and some points occasionally overlooked, and we add a few thoughts of our own. It is not meant to be a comprehensive review. In the last section we offer some practical ideas on the implementation of testing programs in the field.

## TESTING

### Experimental Design

The function of experimental design in tree-improvement research is to permit the separation of genetic from environmental effects on the phenotype (performance or appearance) of the tree. While many kinds of experimental designs have been devised *(Cochran and Cox 1957)*, only two are of wide applicability in tree improvement: completely randomized and randomized block. The essence of both is replication and random location of each clone in the experimental area. (We use clones for illustration, but the designs apply equally well to other genetic units such as families, provenances, varieties or cultivars, and species.) One replicate of a clone is defined as a plot of one or more individual trees.

The completely randomized design is the simpler of the two. It consists of two or more plots of each clone randomly located within the entire test area.

The randomized-block design is more commonly used, however; and it has certain advantages. It differs from the other in that replicates are grouped into two or more spatially distinct blocks. Thus, one plot of each clone is randomly located within each block, not within the entire test area, and the number of replicates equals the number of blocks. The randomized-block design is particularly useful when large environmental differences exist over the test site. Used correctly, this design enables one to "block" much

of the environmental variation, thus permitting greater accuracy in detecting genetic differences.

Optimum numbers of replicates and of trees per plot cannot be determined *a priori* for any particular test site, and they depend also on the particular traits being measured. Purely statistical considerations indicate as many replicates as possible. However, in practice the number of replicates is usually determined by the amounts of space, plant material, personnel, and money available. To a lesser extent the same is true of plot size, but forest geneticists usually opt for sizes of 4 to 10 trees *(Wright and Freeland 1960)*. Similar plot sizes would be best to use in urban-tree improvement when experiments will consist of rectangular plantations with contiguous plots.

So far we have discussed only the design of single experiments or plantations. Another kind of replication to be considered is repetition of entire experiments in many different environments (for example, different cities). The principal purpose of this is to obtain a measure of clone-environment interaction. (Clone-environment interaction exists if the best clone in one environment is not the best, or is best by a smaller margin, in another environment with respect to any one trait.) Although interaction often occurs, it is seldom possible to determine exactly what environmental factor it is associated with. Thus, while experiments on two different sites could be sufficient for detecting interaction, it might not be possible to recommend one clone over another for any but those two sites.

For this reason, and because plant material is usually limited, Wright *(1973)* recommended testing on a large number of sites with few replications at each, rather than on one or a few sites with many replications. If unexplainable interaction occurred, recommendations based on the multiplantation experiment would be more broadly applicable because information would be available from more sites. The main drawback with this suggestion is the loss of statistical accuracy (due to fewer replications) that would occur if a desired condition for testing, such as an insect infestation, could be obtained at only one test site.

Testing is best done at some age past the nursery stage because of the ever-present possibility that juvenile and mature performance will not be closely correlated. But even if nursery plantings are not considered part of the test, they should still be arranged in an adequate experimental design, preferably randomized blocks. Nursery-induced effects on performance can persist for many years after field planting, sometimes falsely giving the appearance of genetic effects *(Wright 1973)*. This problem can be avoided if replicates are blocked in the nursery and the blocks are retained without mixing when the trees are field-planted. Nursery effects then simply become a part of easily measured block, or environmental, effects.

### Test Material

The kind of genetic units tested must correspond with the method by which selections will be propagated. Tests of provenances from different parts of a species' natural range are common in forest-tree improvement, but they are designed for seedling propagation of superior provenances. If vegetative propagation will be used, as is common in the landscape-tree industry, the breeder must test clones or clones on seedling rootstocks. A well-designed test of different provenances has little direct utility in selecting superior clones unless each tree representing a provenance is cloned and replicated in the test in addition to the provenances themselves. Unfortunately this can greatly increase the size of the experiment. All other things being equal, a test of 10 clones in each of 20 provenances is 10 times as large as a test of the 20 provenances alone.

Then why not simply begin with a clonal test of some "selected" trees and disregard provenances altogether, as is

sometimes done? Genetic differences often increase as relatedness among individuals decreases. Thus, differences among provenances from various parts of a species' range often exceed differences among families from the same provenance. Families, in turn, usually differ more than individuals that have the same parents. Without prior knowledge of the variation pattern within a species, it is best to begin with as broad a base of genetic variation as possible.

While combined provenance-family-clonal tests can be cumbersome, they have been used in some improvement programs. An alternative, if time is not limiting, is to test provenances and families first and then do a clonal test of individuals from the best families.

New breeding efforts with some of the more commonly planted species will face a fair wealth of clones marketed by commercial nurseries and in common use by the public. While these clones have almost all been selected for appearance rather than performance *(Santamour 1971)*, they must be given more weight then would otherwise be warranted by their proved superiority to survive under conditions of urban stress. These clones have overcome the considerable hurdle of being successfully introduced into trade, and they are readily available. Thus, new breeding programs should incorporate "old" selections into their testing phases, not only to evaluate them further but also to serve as standards of comparison.

### Testing Conditions

Broadly speaking, testing may be done either in the field under environments similar to those that occur in actual practice (for example, city streets) or in artificial environments in the greenhouse or laboratory. When choosing between the two methods, it is well to remember that no testing situation is completely satisfactory—unless it be establishing tests in every location where selections will eventually be used. The only way to determine with certainty whether a tree will perform well on a particular city street is to actually plant it there!

It is obvious, though, that field conditions more closely represent the environments in which the products of the breeding program will be grown. Artificial environments can seldom be made to equal the complexity of natural conditions. Thus, field-testing will probably be the more generally useful of the two methods in urban-tree improvement. On the other hand, problems with field-testing, such as the difficulty of obtaining stress factors at desired levels and times, favor the use of artificial environments for some testing situations. This is especially true with studies of resistance to insects and pathogens—artificial tests are sometimes the only ones practicable.

The decision of whether or not field-test should take into account the trait or traits in question. If information on many traits is desired, or if it is impossible to anticipate all the traits that may be important, the clones should be field-tested. The reason for this is that environmental stress conditions cannot be made complicated enough in artificial environments to give reliable information on more than one or two traits. Field testing is also recommended if the traits under consideration may be complex ones—that is, affected by more than one genetic mechanism or environmental factor. Such traits show clone-environment interaction; when measured in two different environments they are best regarded as two traits rather than one *(Falconer 1960)*. It is possible that most traits like growth rate and resistance to specific insects and diseases fall in this category. If the interaction is large and not interpretable, as discussed above, field-testing in many locations may be necessary.

## EVALUATION

Evaluation proceeds in three steps: measurement, statistical analysis to determine if genetic differences are present, and equating the measurement scale to

degrees of quality. While what is good for one purpose may be poor for another (for example, high number of fruits per tree), the determination of quality for any given trait is usually automatic and needs no further consideration here. Furthermore, a statistical analysis is usually essential for valid, irreproachable interpretation of data; but even an elementary discussion of statistical analysis is beyond the scope of this paper. Let it suffice to say that a properly replicated and randomized experiment is amenable to statistical analysis. We would, however, like to discuss briefly the measurement of traits. Proper measurement techniques are not always obvious and can greatly influence the accuracy and intelligibility of results.

The choice of traits to be measured depends, in general, on the species being studied and the use to which it will be put. However, some aspects of the choice pertain to the evaluation process itself. In particular, every effort should be made to choose traits that are as simple and basic as possible. As stated above, complex traits have a greater probability of being associated with clone-environment interaction, an undesirable situation when it comes to putting results into practice. Furthermore, complex traits sometimes have little meaning to someone who did not make the measurements. To take an extreme example from the literature, a trait like overall quality—even if defined by a list of criteria—is meaningless to arborists who prefer to emphasize different factors when judging a tree's performance or appearance.

Sometimes it is possible to measure a trait in several different ways. For example, insect damage may be measured as the number of trees per clone with attacks, number of trees per clone killed by attack, number of attacks per tree, and other manifestations of insect predation appropriate to the insect in question. These, by the way, are perhaps less complex traits than some combined index of insect damage.) In such cases it is helpful to use all appropriate measures if time permits. Even if they are highly correlated, one will invariably give a higher significance for genetic differences in the statistical analysis. That this method or trait is actually the best may not be apparent until the statistical analysis is performed.

All data must, of course, be in numerical form for analysis. This is easy with quantitative traits like height, but even qualitative traits may usually be expressed numerically. When possible this should be done objectively, but subjective ratings can be used if the trait and scale of measurement are carefully defined. For example, foliage color can be measured objectively, but tediously, by wavelength or correspondence with color-chart values. We have measured winter foliage color of Scotch pine by visually rating trees on the basis of a numerical scale corresponding to colors from green to yellow. Results were intelligible and surprisingly consistent for sets of measurements made at different times and by different observers.

With any measurement system it is important that distances between successive points on the scale be equal. It is particulary necessary to be careful of this when using subjective ratings, but quantitative measurements can also be incorrectly used. For example, one might devise a scale of air-pollution damage ranging from 0 (= dead) to 20 (= no damage). However, the difference between 0 and 1 (the difference between dead and living) might not be biologically equivalent to the difference between 19 and 20 (the difference between very little and no damage). A better method would be to score mortality separately and rate damage on a scale of 1 (= very severe) to 20 (= no damage).

Comparisons among clones are always relative—other conditions will almost invariably result in different absolute values of performance or appearance. Thus, the scale of measurement units should correspond with the range of values that

exist in the experiment at hand. Statisticians prefer a scale of about 30 steps between the smallest and largest measurements in a set, but shorter scales may be used if necessary *(Sokal and Rohlf 1969)*. An important point—often overlooked—is that measurements can be excessively precise. While there is no simple formula for the relationship, a useful rule of thumb is that precision in measurement decreases in importance as the variation among trees within a plot increases.

## APPROACHES TO FIELD-TESTING

Testing in artificial environments obviously presents no particular problems unique to urban-tree improvement. However, the opposite is true of field-testing because of the unusual nature of field conditions like highways and city streets. Often space is limited, and usually access is controlled by some agency or office of the government. Certainly few research institutions own land entirely suitable for testing in urban environments.

Much of the problem lies, as Santamour *(1968)* has pointed out, in the stratified nature of the landscape-tree industry. In successive stages, the tree passes through the hands of the producer (nursery), planter (arborist), and consumer (public); and the planner (landscape architect) and research institution can sometimes add additional levels. None is in complete control of the whole tree-growing operation. Because the testing process spans all these levels, it will be necessary to develop good coordination in order to implement sorely needed testing programs.

Few attempts have been made at large-scale field-testing in urban-tree improvement. The best known and probably largest program is that of the Ohio Agricultural Research and Development Center, which is testing 128 species and cultivars of shade trees in one location *Chapin and Kozel 1975*. Lighty *(1975)* has proposed an ambitious plan whereby each cooperating member of the American Association of Botanical Gardens and Arboreta would agree to plant and evaluate cultivars of certain species according to agreed-upon procedures and cultural conditions. A final report would summarize the results of all test sites.

Both schemes, however, circumvent the question of how to field-test in urban environments, the conditions in which superior selections will be expected to survive. What are some of the specific problems of testing in urban environments, and how might they be overcome?

### Space and Experimental Design

Open spaces suitable for the establishment of large test plantations are difficult to obtain in urban localities. One alternative, used by Dr. Townsend in testing his red maples, is to plant along highway rights-of-way. These areas often compose a major share of the idle land in large cities, and because of their size they present few problems in experimental design. They are particularly suitable for testing if a major use of selections will be highway beautification.

Container-planting is another use that lends itself well to testing. The greatest stress factors for trees growing in containers are probably edaphic ones: lack of moisture and nutrients, extreme soil temperatures, etc. If above-ground stresses assume lesser importance, trees for container planting could be adequately tested anywhere, as long as they are grown in containers. Such testing presents no exceptional problems associated with space or experimental design other than the actual construction of the containers.

Testing in containers would also indicate, to some extent, ability to survive in narrow "tree lawns" (spaces between street curb and sidewalk) or small plots of ground in parking lots. But if the major uses of new selections will be for these purposes, tree lawns and parking lots are the best test areas. Such tests would, of course, be limited in size by the number

of available planting sites in cities. A recent survey of tree planting activities by municipalities in the northeastern United States indicated that most plant only a few hundred trees per year *(Gerhold et al. 1975)*; and presumably only a portion of these sites would be appropriate for testing clones of a single species. Thus it may be necessary to screen the clones in other test situations and eventually test only a selected few on tree lawns and other strictly urban sites.

The sizes and locations of planting sites will determine to a large extent the experimental design to be used in an urban test. One ideal situation would be two or more strips or double strips (both sides of street) of tree lawn, each large enough to accommodate a full set of clones. One plot of each clone could be randomly planted within each strip. The strip would then constitute one block of a randomized block design. If several strips are available but are too small for a full set of clones each, a system of incomplete blocks could be devised if the composition of each is carefully planned *(Cochran and Cox 1957)*.

Probably a more common situation for a test would be a disorganized system of sites distributed throughout a city and varying in size from single-tree locations to entire city blocks or more. If that is the case, one could still resort to a completely randomized design and make no attempt to group replications into blocks. Besides the difficulty of measuring such scattered plots, the main disadvantage with such an experiment would be the variation in performance caused simply by large, unblocked, environmental differences over the test area. This error variation could easily be large enough to make detection of small genetic differences impossible.

Along the same line, if it is possible to use the randomized-block design, environmental differences among plots within a block should be made as small as possible. In most kinds of testing it is possible to control this by manipulating the shape and orientation of blocks with respect to environmental gradients. This would not be possible when testing along city streets because the shape (linear) and direction are predetermined by the sites themselves. Furthermore, average distances (and probably environmental differences) among plots are greater in linear blocks than in areal blocks of the same size. Thus every effort should be made to reduce the length of blocks by either limiting the number of clones to be tested or by reducing plot size to one or two trees. This, and the fact that mortality in street plantings is usually less in forest plantings, will favor the use of smaller plots than is common in forest-tree-improvement research.

### Genetic Diversity

The aesthetic undesirability of having a diversity of trees along one street is sometimes suggested as a drawback to testing in cities. This is true if the material being tested contains a number of species or clones of one species that differ widely in appearance. However, in testing performance of clones within a species, this consideration is probably inconsequential unless trees of very unusual form are included. The greatest genetic gains in performance will come from selecting among thousands of wild plants rather than among the few cultivars of a species. Any group of wild plants chosen randomly with regard to appearance will look much more homogeneous than the same number of clones previously selected for unusual branch angle, foliage color, or leaf shape.

### Means of Outplanting

Few public research institutions have facilities and manpower to grow and plant trees of the size necessary for street plantings. One means of circumventing this problem would be to establish cooperative programs among the institutions, commercial nurseries, and municipal arborists. The institution would furnish the seed or seedlings of material to be

tested; the nurseries would propagate the clones and grow them to salable size; and the purchasing agencies would plant the trees according to certain constraints of arrangement and conditions of care specified by the breeder.

The arborist would, of course, have to agree to cooperate; but his time commitment need only be minimal. He would only have to specify the locations to be planted and the number of trees needed for each. From this information the breeder would devise the experimental design and determine which clones would go in which locations. (With minimum precautions, randomization would be automatic.) Before the sale, the breeder and nurseryman would temporarily label the trees according to intended location (for the arborist) and identify them (to enable the breeder to later map plot composition).

A means of entirely avoiding the problems of outplanting when testing clones now in use is to simply evaluate the performance of trees already growing on city streets. Such evaluations are in progress at the Ohio Agricultural Research and Development Center *(Chapin and Kozel 1975)* and The Pennsylvania State University. This is not fundamentally different from testing and evaluation as we have discussed them so far—it is just that the test is not planned when the plantings are made.

For this reason, however, sample plots must be selected carefully. There should be at least two for each clone; and they should be random with regard to age, time of planting, cultural practices, and planting location. It would not be valid, for example, to compare two clones in traits affected by age if all trees of one clone are 15 years old and all trees of the other are 25 years old. Similarly, comparisons in traits affected by site would not be valid if all trees of one clone are located in one city and all trees of the other in another city. The statistical effect of lack of control over these nongenetic variables is to increase error variation and make comparisons less accurate.

## SUMMARY

Testing and evaluation of urban trees will be more difficult than they are in breeding programs with other kinds of plants. But the hurdles are not impossible to overcome. If breeders use proper techniques and obtain the cooperation of nurserymen and arborists, rigorous testing and evaluation programs can be developed. Only then will methodically acquired knowledge begin to replace the trial-and-error techniques on which arborists must now rely, and we will be able to approach with greater assurance the ultimate test of improved trees—getting them into use.

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# HOW TO NAME, REGISTER, AND PATENT SELECTED CULTIVARS OF AMENITY PLANTS

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*ABSTRACT.* A consideration of the historical development of the concept and term "cultivar" precedes a discussion of some aspects of the choice and validation of new cultivar names, methods for the documentation of these names, and a brief survey of plant patents and trademarks. The registration of all cultivar names, through national or international registration authorities, is strongly recommended.

## HISTORICAL ASPECTS AND CONCEPTS

BOTANISTS AND TAXONOMISTS who devote research time to the nomenclature of cultivated, ornamental, and economic plants have often been held in disrepute by the fraternity of commercial and professional plantsmen and plant breeders, because of the seemingly never-ending parade of changes in rank and name, botanical and horticultural, proposed and published in the trade and professional literature.

An excellent case in point was the rejection of the name *Viburnum fragrans* Bunge in 1966 by W. E. Stearn of the British Museum of Natural History. In a paper in TAXON, the official international Association of Plant Taxonomists and the International Bureau of Plant Taxonomy and Nomenclature, he rejected this name for reasons of priority and was obligated to erect a new specific epithet—*Viburnum farreri* Stean, which is now considered the correct name. Name changes such as this, and the many others that have occurred, however odious they may seem, are established in good faith and are the result of strict adherence to the internationally devised and accepted concepts, precepts, procedures, and rules (such as the Rule of Priority) specified in the INTERNATIONAL CODE OF BOTANICAL NOMENCLATURE *(Stafleu and others 1972)*.

This perpetuating document was created to insure nomenclatural stability the world over; and it is revised every 5 years to reflect developing trends and concepts, to provide new interpretations, and to clarify apparent ambiguities. When the taxonomist, following this code, changes specific or generic names, or demotes a species name to the botanical rank of *varietas* or *forma* or sinks it into the synonomy of another species, it may take years for these new names or rank assignments to overcome resistance and replace

the earlier incorrect name in the literature and commerce.

There have been numerous editions of the BOTANICAL CODE, the latest published in 1972 following the 1969 International Botanical Congress held in Seattle. I do not propose to discuss the rules of botanical nomenclature or their ramifications in any great depth here. However, it is important to appreciate them, as they are the basis for, and provide the format for, the INTERNATIONAL CODE OF NOMENCLATURE OF CULTIVATED PLANTS *(Gilmour and others 1969)*. This code, which can be referred to as the *Horticultural* or *Cultivated Code*, was certainly an outgrowth of the *Botanical Code*.

Since the publication of Philip Miller's THE GARDENERS DICTIONARY *(6th edition, 1752)*, which is the starting reference for the nomenclature of cultivated plants, botanists and horticulturists have confronted difficulties and a certain degree of frustration in developing mutually acceptable and feasible procedures for the naming of cultivated plants. The history of the literature and attendant verbal clashes often has produced an unfortunate attitude that "Never the twain shall meet". This is an erroneous sentiment, for as we all know, the common meeting ground for both is the same raw material. Although their purposes and emphases may be divergent, they certainly are not mutually exclusive.

Horticulturists and plant breeders are involved with development, selection, distribution, and cultivation of superior environmental, amenity, and economic plants. On the other hand, taxonomists, who by definition are also nomenclaturists, are interested particularly in developing bodies of scientific classification knowledge (including phylogeny) for the whole plant kingdom, but generally as applied to naturally occurring plants with geographic and/or ecological patterns of distribution.

The taxonomist who devotes energy and research to cultivated plants, in addition to being fairly rare, is often suspe to both his botanical and horticultur colleagues. By the former because the r search materials are not exclusive "wild" or naturally occurring, and by t latter because of the seeming inapprop ateness of the principles of botanical ta onomy and nomenclature to cultivat plants that have arisen as the result various processes in cultivation, or th were selected in the "wild" and subs quently introduced into cultivation.

Numerous attempts, mostly unsucces ful, were made before 1953, to reconci compromise, and apply the concept a accepted procedures for naming "wil plants to cultivated plants (in the sen of cultivated or horticultural varieti that are synonoymous with horticultur or cultivated forms). The early history these struggles, and the naming of cul vated plants, using the *Botanical Co* and the subsequent production of a *C tivated Code*, is well recorded by W. Stearn of the British Museum in the i troduction to the first edition of t INTERNATIONAL CODE OF N MENCLATURE OF CULTIVATE PLANTS, published in 1953 by the Roy Horticultural Society.

It was with this *Cultivated Code*, separate publication independent of t *Botanical Code*, that the new nomenc tural category or rank called "*Cultiva* was introduced into the hierarchy plant classification and internationa recognized as the lowest nomenclatu element in the scale. Here at last was distinct term, exclusively reserved plants in cultivation that arose in cul vation, or were selected from cultivat or naturally occurring populations a subsequently introduced into cultivatio It is important not to lose sight of t fact that this *Cultivated Code*, with precise set of guidelines or rules for c ating and applying cultivar names unique selections or clones, was conceiv by botanical taxonomists and nomenc turalists in 1950 at the Stockholm Int national Botanical Congress.

Never again can a cultivated or horti-
ıltural variety, now known as a "*culti-*
*ar*", be confused or interpreted as
ynonymous with the botanical categories
r ranks of *varietas* or *forma* (plural:
*arietates* and *formae* respectively). As
istinguished from the horticultural rank
f cultivar, the botanical ranks, including
ıat of *subspecies*, possess known, more
r less predictable natural geographic dis-
ibutions (though diffuse, particularly
ı the case of *formae*), or recognized eco-
gical preferences combined with one, or
referably more, discernible morphologi-
ıl features.

In review, the compound coined term,
*ıltivar* from "CULTIvated" and "VARi-
:y", is now fully accepted by botanists
s having priority over the earlier terms
"cultivated" or "horticultural" variety,
ıd is not biologically or nomenclaturally
ynonymous with or homologous to the
otanical term *varietas*. Credence to the
erm cultivar is emphasized and legis-
ted for as article 28, page 35, in the
*ıternational Code of Botanical Nomen-*
*ature* (1972):

> Variants of infraspecific rank, which arise in cultivation through hybridization, mutation, selection, or other processes, and which are of sufficient interest to cultivators to be distinguished by a name, receive cultivar epithets preferably in common language (i.e. fancy epithets) markedly different from the Latin epithets of species and varieties. Examples: *Anemone* X *hybrida* 'Honorine Jaubert,' *Fravinus excelsior* "Westhofs Glorie,' *Juglans regia* 'King', *Primula malacoides* 'Pink Sensation' and *Viburnum* X *bodnantense* 'Dawn' are variants which have arisen in cultivation and are recognized as cultivars. Variants found growing in the wild, which are brought into cultivation, may also be given cultivar epithets. Examples: *Phlox nivalis* 'Gladwyne' and *P. nivalis* 'Azure' are variants taken into cultivation from the wild for their horticultural interest.

This definition is further amplified and
dfined as article 10, page 12, in the *In-*
*tnational Code of Nomenclature of*
*Cltivated Plants* (1969):

> The international term *cultivar* denotes an assemblage of cultivated plants which is clearly distinguished by any characters (morphological, physiological, cytological, chemical, or others), and which, when reproduced (sexually or asexually), retains its distinguishing characters. The cultivar is the lowest category under which names are recognized in this Code. This term is derived from *cultivated variety*, or their etymological equivalents in other languages.

Because an excellent discussion of "The Concept of the Cultivar" by James S. Pringle has been published, there is no need to further define the concept.

However, the term and concept of the cultivar met with considerable resistance throughout the 1950s and 1960s, and to some extent into the current decade. This resistance comes from some "classical" botanists who do not recognize that plant differences can arise in cultivation as the result of various processes, and from some horticulturists and plantsmen who do not wish to change their ways. It is heartening therefore to realize that the published works of the majority of horticultural authors over the past 4 or 5 years utilize the cultivar concept and assiduously avoid the use of the terms, abbreviations, or typographic techniques such as "cultivated variety", "horticultural variety", "variety", "var.", "f.", double quotation marks, or even polynomals without any rank designation.

An example of correct usage is the excellent volume, DWARF SHRUBS (1974) by Donald Wyman, one of the most eminent horticultural spokesmen in the United States. In this book cultivar names are used consistently and are enclosed by single quotations marks (e.g., *Ilex crenata* 'Mariesii'). Single quotes are one of the two alternative typographical methods provided for in the *Cultivated Code* to designate cultivar names. The other equally suitable and correct method is to precede the cultivar epithet with the abbreviation "cv." (e.g., *Ilex crenata* cv. Mariesii) without single quotation marks. In either case, the first letter of the cultivar name is always capitalized. Typographical underlining which indicates italics is never used for cultivar names, but is reserved for Latin names at any botanical rank.

## CHOICE AND VALIDATION OF NEW CULTIVAR NAMES

Recently the American Association of Nurserymen published a neat and compact guide (undated, but published in 1974) entitled NAMING AND REGISTERING NEW CULTIVARS. I strongly recommend that any person—commercial, academic, or governmental—who is in the business of producing, selecting, naming, and ultimately distributing superior clones of amenity and environmental plants, obtain a copy of this booklet, as well as the 1969 *Cultivated Code* on which the booklet is based. The guidelines specified in both publications are clearly stated, particularly entries 1 through 21 in the American Association of Nurserymen booklet which, although based upon articles and recommendations in the *Cultivated Code*, is somewhat easier to follow, because it rephrases some of the more technical language and examples.

Several major categories need to be stressed, however, so that there will be no doubt as to the correct procedures and requirements for selecting, documenting, and validating cultivar names for new superior selections or clones.

1. Any person may apply a cultivar name to a selected plant as long as the plant has not previously been legitimately named. A new cultivar name cannot be erected and applied to a plant for commercial or commemorative purposes if that plant has a perfectly legitimate and valid name in accordance with the rules of the *Cultivated Code*.

2. A legitimate cultivar name may be in any modern language, and should preferably be a fancy name. It may not be in Latin or have a Latinized ending. The cutoff date for this rule is 1 January 1959. A Latinized cultivar name published after that date, even if accompanied with an appropriate description, is automatically invalid and cannot be used. Latinized cultivar names published before 1 January 1959, with or without a description of any type, are automatically regarded as legitimate and valid.

3. To be considered valid after 1 January 1959, a cultivar name in the new fancy, and modern language must b suitably published and accompanied b an adequate description or a reference t a previously described entity, either a cultivar or botanical rank, that has a illegitimate and invalid epithet. Also, t be valid and legitimate, a cultivar nam published after 1 January 1959 must no consist of more than three words—an individual letters, an abbreviation, or numeral count as one word. "Suitabl publication" is defined in the *Cultivate Code* by articles 37 and 38, page 2( Official registration of a new cultiva name by a national or international regis tration authority appointed by the Inter nation Commission for the Nomenclatur of Cultivated Plants of the Internationa Union of Biological Sciences automatic ally implies publication of the name an is a preferred method by which to vali date a name.

Publication vehicles such as AR NOLDIA from the Arnold Arboretum BAILEYA from the Bailey Hortorium the JOURNAL OF THE ROYAL HOR TICULTURAL SOCIETY and its com panion yearbooks, BULLETIN OF TH AMERICAN ASSOCIATION OF BO TANIC GARDENS AND ARBORETA HORTSCIENCE, plant society litera ture, and other technical or horticultura journals that have reasonably wide ci culation, are most desirable.

However, since registration of a culti var name is not mandatory or obligatory the originator, who may also be th namer, may elect to publish a new culti var name with the validating descriptio in any journal, book, checklist, or nurser catalog of his choice. Nursery catalog en tries for new cultivar names are ver common and are perfectly legitimate pub lication resources, as long as the catalog are dated (commencing 1 January 1959) the formulation of the name adheres t the rules of the *Cultivated Code*, and th

validating description is adequate. Too often, however, because of space and financial limitations, the descriptions accompanying new cultivar names that appear in nursery catalogs are grossly inadequate.

In addition to the morphological characters and ecological features, if any, that serve to distinguish a newly named clone or selection from its closest clonal allies and all other named cultivars, or parents within the genus, an adequate description should include all data known about its history, parentage if of hybrid origin, and the names of the individuals responsible for selection, introduction, naming and distribution. The inclusion of such details, together with diagnostic morphological characters in the descriptions of new cultivars, will go far in preventing nomenclatural and identification problems from developing, and will greatly assist the taxonomist and registration authority in untangling existing problems, particularly those of synonomy and those resulting from the proliferation and multiplicity of cultivar names.

4. A cultivar name for a recent selection or clone must not duplicate a name already in use for a different plant within the genus. The *Cultivated Code* does allow, in article 48, page 22, the re-use of earlier, validly published, fancy names if proof exists that, after at least a 10-year lapse, the plants to which the names were originally applied are no longer anywhere in cultivation. This is a controversial article; and most registration authorities, who have the ultimate authority to reject or to accept any particular cultivar name, prefer to avoid *any* name duplication, particularly within woody genera.

5. The Rule of Priority or Homonyms holds in the application of cultivar names, as it does for botanical ranks and categories. This means that two different plants or clones in a genus cannot have the same cultivar name, and the earliest legitimate and validly published application will automatically have priority. The plant or clone having the latest application of the name should be given a new and different name. Similarly, different names cannot be applied to two or more plants that are proved to be identical and of the same clone. The earliest legitimately published epithet is, accordingly, granted validity and priority.

6. Numbers or abbreviations used to designate pedigrees, and hybrid formulae, should not be used as cultivar names, nor as a partial element of cultivar names. Botanical or common names of genera or species that are ambiguous, or could lead to confusion, should not be used as cultivar epithets. Common names have no nomenclatural or taxonomic status or stability; and if used at cultivar rank after 1 January 1959, they are to be automatically rejected and considered invalid. It is strongly stressed that cultivar names that have never been published formally, but appear only as *nomen nuda* on plant labels, arboreta or botanic garden accession cards, invoices, shipping forms, and the like, are considered to be invalid until such time as they are legitimately published with a description, and preferably registered.

7. In union with an irrevocable ruling in the *Botanical Code*, the *Cultivated Code* recommends emphatically that the published description of a new cultivar be accompanied by an illustration of the plant, and that a preserved, pressed and dried, authentic (clonotype) specimen, together with a colored illustration, be deposited in a herbarium. This fact should be cited with the description. Although this practice is only a recommendation, strict adherence to it, and making it a firm rule or article in the next edition of the *Cultivated Code*, will insure further that any particular cultivar name applied to a specific and distinct plant or clone, which may for decades or even centuries be propagated by asexual methods, can never be re-used and never confused with any other plant or clone within the genus. Herbarium specimens, registration, and detailed historical and morphological descriptions are all ele-

ments of documentation essential to correct application of cultivar names. This subject will be expanded later.

8. Several other fine points primarily regarding orthography and construction of cultivar names are established in the *Cultivated Code* and the American Association of Nurserymen booklet, and they are essentially self-explanatory. To summarize: it is recommended that the following categories of names should not be used as cultivar epithets: the articles "a" or "the"; nearly identical names that could cause confusion; names that are too long; common descriptive terms, forms, or titles; names of countries or states used alone; numerals intended as trial or temporary designations; names of politically conspicuous individuals; names that exaggerate the plant's merits; and abbreviations.

9. The format for naming new interspecific or intraspecific hybrid clones arising in cultivation is identical to that of all other classes of cultivars. It is appropriate and recommended practice; however, new hybrid cultivar names should be preceded, in publication, with the hybrid formulae designating the parents, or with the hybrid group name that encompasses several similar and obviously closely allied, but distinguishable individuals (article 26, page 16, of the *Cultivated Code*).

## REGISTRATION AND DOCUMENTATION OF CULTIVAR NAMES

Registration of all cultivar names within a particular genus, or series of genera, is the responsibility of the internationally appointed registration authorities and their designated registrars. Duties implicit in this function are to record all cultivar names proposed for cultivated entities, to establish which names are valid and legitimate and which are clearly synonymous, and to include all names in a published register. To accomplish these duties adequately, the registration authority must interpret the *Cultivated Code* and assure that all cultivar names (particularly newly erected ones) adhere to the rules of this code. The main objective of registration is to stabilize and standardize the nomenclature of cultivated plants. This goal is accomplished by recording, documenting, and publicizing the origins, discoverers, namers, introducers, and distinguishing features of the newly named clones.

The modest information available for older cultivar names is scattered throughout multitudinous nursery catalogs and horticultural and botanical literature. Such information is often of dubious authenticity, with the result that the names of individuals directly responsible for originating, discovering, and naming clonal selections are lost to posterity. Often the history of origin and introduction is so obscure that numerous nomenclatural and synonymy problems can never be resolved.

Registration provides permanent recognition to persons involved with the discovery, introduction, and naming of new cultivars by full documentation and suitable publication of their names. It also preserves valid cultivar names and guarantees, in good faith, that the names of the originators, selectors, and introducers always will be associated with the valid and legitimately published names. Registration prevents any possibility of confusion that could arise from the duplication of cultivar names for different plants, or the application of two or more different cultivar names to a single clone. It also helps to distinguish cultivar names from common and botanical names and ranks.

International registration of cultivar names does not imply any judgment on the part of the registrar of the ornamental or horticultural merits or attributes of any clone, although it is hoped that the applicant for a plant registration would provide adequate documentation to be published by the registrar. The *Cultivated Code* clearly instructs the registration authorities to avoid any judgment,

prejudicial or complimentary, regarding the plant whose name is being registered. The only judgments that are to be made must relate directly to the validity and applicability of the cultivar name being registered.

Plant registration is not legally binding in the same sense as national, regional or state plant patents or trademarks. However, international registration of cultivar names is widely supported, in theory and in practice, by botanists, horticulturists, and plantsmen the world over.

The mandates given to the appointed registration authorities by the *Cultivated Code* are quite specific (articles 53, 54, 55, and 56 and appendix I, pages 23-25), but the implementation of the responsibilities and procedures may vary among these authorities—which may be plant societies, such as the Holly Society of America, Inc., or botanic gardens, arboreta, or research institutions, such as the Arnold Arboretum and the National Arboretum.

The most important aspect of registration is the published documentation in formal checklists, registration lists, or cultivar enumerations for specific genera such as those produced by the Arnold Arboretum in ARNOLDIA, or by the National Arboretum in its "Contribution" series. These published lists are the basis of cultivar nomenclature; and it must be emphasized that international registration is only a published and documented record of a name or epithet, and does *not* apply to the actual plant or clone being named, but offers protection only to the *name* being proposed. The American Association of Nurserymen booklet (item 22, page 6) is somewhat misleading in indicating "Registration of New Plants". It would be correct, however, to imply that ". . . while the registration of a new cultivar [name] has no effect on obtaining a plant patent or breeder's rights [for a particular plant or clone], it is helpful in enforcing the rights granted by a patent or breeder's rights [for a particular plant or clone]". (Words in brackets are additions I consider desirable.

Within the scope of registering cultivar names is the extreme importance of herbarium specimens for documenting the plant being named and to help in authenticating cultivar names, particularly of woody plants. This cannot be overemphasized when cultivated plants and their wild allies or ancestors are being scientifically investigated, or when the progress and results of hybridization programs that utilize biochemical and cytological analyses, and are designed to produce superior and improved cultivars, are being documented.

Registration forms with detailed instructions are available from the appropriate registration authority. The generic or family specialities and addresses of these authorities are listed in the American Association of Nurserymen booklet NAMING AND REGISTERING NEW CULTIVARS and in the 1974 edition of the DIRECTORY OF AMERICAN HORTICULTURE, published by the American Horticultural Society. Although the actual format of the registration applications may vary, in general most authorities request the information specified in appendix I of the *Cultivated Code*. The National Arboretum, authority for several woody genera, and the Arnold Arboretum, authority for all woody genera not otherwise assigned, also request hardiness ratings, color readings, photographs, and herbarium specimens, and occasionally living plants in lieu of herbarium specimens. A modest fee may also be requested by some authorities to facilitate handling and processing.

## PATENTS AND TRADEMARKS

The United States Federal Plant Patent Act of 1930, amended in 1956, specifies that any person who invents or discovers and propagates a new variety (should read "cultivar") by asexual procedures may obtain a patent through the Plant Patent Office. When an application

for a plant patent is submitted, it must be in very legalistic and often cumbersome language, and must present unequivocable proof that the new cultivar is indeed a unique invention or discovery, morphologically distinct from all other cultivars of that particular group. Furthermore, the applicant must guarantee to provide an adequate supply of asexual propagations to the public.

When the specifications of a plant patent have been met, the applicant is offered the protection that under law only he or his licensee may legally propagate the unique plant for a regulated time period. Note that a plant patent protects the actual plant entity or clone, whereas registration offers international acceptance and protection of the cultivar name and nomenclatural stability for a clone. A plant patent does not affect the name of a cultivar or clone, although a name may be included, if desired, in the patent specifications. A plant that has been awarded a patent may at any time be given a cultivar name, which accordingly may then be registered.

Often legal agreements are essential to protect ownership rights, and advice from a patent lawyer is recommended. This is particularly critical if a plant thought to be unique and new is merely "discovered" in the wild or in cultivation, and is not the direct result of the prospective applicant's hybridization or selection programs. Answers to the more complex questions of plant patents can be obtained from the Plant Patent Office of the United States Department of Commerce, Washington, D. C.

The United States Plant Variety Protection Act of 1970 offers essentially the same type of protection to the applicant and inventor as does the plant patent. The primary and most critical difference is that this act is applicable only to sexually reproducing plants that may be deemed as new and unique, and whose distinctive characteristics are reliably stable from generation to generation by means of seed propagation. Like patents, however, the Plant Variety Protectio Act does not provide any regulation, pro tection or registration of a cultivar name In contrast, the 1964 Plant Variety an Seeds Act of Great Britain gives protec tion and rights to plant breeders, but als makes registration legally compulsory fo some genera and species, primarily seed reproduced ornamentals and some vege tables.

Under United States law, cultiva names may not be trademarked, an trademarks cannot supersede or include valid cultivar name. Some states in thi country, and in certain other countries do allow cultivar names to be trade marked. In these cases the trade-marke name can be incorporated into a registra tion list of cultivar names only with th express permission of the holder of th trademark, and then must be clearly in dicated with an ®.

Many of the elements in the foregoin discussion could be expanded to hours o intensive interpretation and analysis. Th basic concepts and procedures must firs be assimilated so that nomenclatural sta bility of cultivars may proceed and b perpetually assured. I close my comment with the suggestion that cultivar name should not be applied in popular litera ture or catalogs before they are approve by the appropriate international registra tion authorities.

Some type of pressure, perhaps lega needs to be applied to attain the goal o registration of all proposed cultiva names. If name registration could be en forced legally before a plant could b listed in a catalog or sold, then onl truly distinct cultivars would be intro duced, and their names would always b in full accord with the rules of the *Culti vated Code*. Many hybridizers and plants men are very conscientious and carefull register their new names. There is residue, however—particularly of nurs erymen—and, I regret to report, of pro fessional academic plant breeders, wh could be more flexible in their attitudes Improvement in the area of voluntary o

enforced registration would be of enormous benefit to the science of taxonomy and the art of nomenclature of cultivated plants.

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# THE NATIONAL ARBORETUM INTRODUCTION PROGRAM FOR NEW AND IMPROVED SHRUBS AND TREES

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*ABSTRACT.* The U.S. National Arboretum introduction program is an integrated program that includes the evaluation of potential new cultivars and stock increase of those plants selected for introduction.

WIDE DISTRIBUTION AND CULTIVATION of a superior new shrub or tree cultivar can be achieved only by a planned introduction program. Achieving the ultimate goal of wide distribution, commercial production, and consumer acceptance depends upon a program that incorporates evaluation throughout the geographic adaptive range, stock increase before introduction, and coordinated release and promotion. The best plant may never attain this goal and subsequently provide the funds for additional projects unless the plant breeder formulates and pursues a planned introduction program.

The research-project yardstick in reality is the production of the best possible plants that get to the largest number of people in the shortest time. The long-time commitment of money, time, and personnel to breeding research of woody ornamental plants can be justified only when the new cultivars are produced in sufficient numbers to be readily available to the public and form a common element in our daily environment.

A new plant may encounter many obstacles before it is widely recognized as a superior cultivar. Not the least of these obstacles is the competition from widely, and often adversely, publicized new cultivars that represent no significant horticultural improvement. Such plants are numerous because practically anyone can select, name, patent, trademark, and introduce a plant.

To be able to surmount competition, a superior cultivar must have distinctive attributes such as outstanding horticultural merits, disease and insect resistance, pollution tolerance, hardiness, propagation capability, landscape adaptability, and the like—attributes that sell the plant first to the nurseryman and finally to the consumer. The plant breeder is challenged with the responsibility not only to critically evaluate potential cultivars and select only the truly superior, but also to assume a large share of the job of selling the new cultivar. The salesmanship of the plant breeder to a large degree delineates the designation of superior cultivar for a new introduction.

The commercial nursery is the final

hurdle and crucial bridge between the plant breeder and the consumer public. The success or failure of a superior cultivar is dependent upon the nurseryman's selling and unrestricted plant dispersal. The nurseryman is a businessman who may or may not have much scientific background, but he is an expert in methods of propagation, production, and marketing necessary to get the plants to the people. So, if a plant is to make it from research into tomorrow's landscapes, the plant breeder must develop it, the nurseryman must produce it, and the public must accept it.

The National Arboretum introduction program for new and improved shrubs and trees evolved as the diverse research projects began to yield introductions. It soon became evident, as the woody-ornamental breeding projects developed and introductions became more numerous, that a specific program was needed to expedite introduction procedures. In 1969 a cooperative program for increasing stock of the new cultivars was initiated to promote introduction. Although this program partially fulfilled the need to increase numbers of plants, it lacked selling impact. A second program—to evaluate potential new cultivars—was initiated in 1971 to assist in the final evaluation of selections under other climatic conditions and hardiness zones before introduction and thus enhance the sell. A brief resumé of these programs previously was presented along with an enumeration of the 40 National Arboretum cultivar introductions *(Egolf 1971, 1972)*. The following discussion of these programs provides models that might assist other research projects in developing introduction programs.

## COOPERATORS

Probably no research institution has adequate facilities and funds to independently develop and pursue an introduction program solely for the products of its research projects. The National Arboretum is no exception. However, in our program a compromise that utilizes the expertise of cooperators has been mutually beneficial to both the plant breeder and the cooperator. The effectiveness of such mutual agreement is dependent upon the selection of cooperators.

There is no research institution so geographically located that it can adequately test and precisely define the area of cultural adaptability of a new plant for such characteristics as cold hardiness and growth response. An accurate appraisal of the response of a particular plant can be achieved by the enlistment of cooperators throughout the range of potential climatic adaptability. Also, limited trials in areas of more extreme climatic conditions might be attempted. Wide distribution of cooperators provides data on the maximum area of plant growth from the evaluation program and allows rapid dissemination of plants from the stock-increase program.

A cooperator must be an individual or institution who will cooperate by making keen observations, detailed notes, and periodic reports. The best cooperators are those who have a special interest in the species or genus, or nurserymen who grow and sell similar plants. Likewise, some arboreta, universities, and experiment stations are so located or have staff that make them ideal cooperators. The list of cooperators may change as other genera or plants become available for distribution, or if an individual or organization fails to provide beneficial cooperation. Periodic review of the cooperator list will make sure that those who wish to become cooperators are recruited and that all participants are active.

## EVALUATION PROGRAM

Critical evaluation of the initial seedling from a population is the most crucial step in any plant-breeding program. Only those seedlings that hold promise of becoming superior cultivars or potential parental clones warrant inclusion in an

evaluation program. The initial selections are propagated and planted in test rows to further evaluate stability of horticultural characteristics. Simultaneously, controlled inoculation of a disease and cultural and propagation studies are pursued. Data from such studies determine the seedling selections for inclusion in cooperative evaluation.

In the National Arboretum program, only rooted cuttings are distributed to assure perpetuation of the genotype, to eliminate any identification problems, and to avoid differential growth response that might result from stock and scion of grafted plants. Although propagation potential may impose restrictions or limit acceptance of selected plants, there are few woody plants in which cuttings cannot be rooted by some technique. It is the plant breeder's responsibility to assess the propagation potential, determine a recommended technique, and advise the propagating nurseryman.

A questionnaire listing data on parentage, horticultural characteristics, pest resistance, pollution tolerance, hardiness, and size and number of plants available for shipment is forwarded in December to each potential cooperator, who may be a nurseryman, a researcher, a botanic garden or arboretum staff member, or an individual with a wide knowledge of a plant group. The cooperator, after reviewing the questionnaire, makes a request for the desired plants. He is then sent for approval and signature a Standard Form Memorandum of Understanding for Evaluation of Potential Cultivars (Exhibit I) with accompanying information on patenting (Exhibit II), that specifically lists the plant material. This memorandum is a legal agreement between the National Arboretum and the cooperator, which prohibits any propagation of evaluation plants until authorized. After receipt of the completed memorandum, the plants (usually three to five, and bearing a code number) are shipped in late January or early February.

Evaluation cooperators are periodically requested to complete report forms that provide specific data on a limited number of characteristics such as hardiness, disease resistance, flowering, fruiting, and general cultural considerations. Probably the most significant and foremost question of nurserymen is the hardiness range that will define the parameters of cultural adaptability. Experience has shown that the fewer and more direct the questions asked, the more meaningful the response. Compilation of evaluator data not only defines the cultivar response and adaptability, but also can assist the plant breeder's isolation of parental clones.

Comprehensive evaluation before introduction, in addition to critical analysis of cultivars, provides both a broad exposure sell and a quantity of stock plants for future mass propagation. The evaluation period of 3 to 10 years, depending on the nature of the plant, can be the most effective sell for the new cultivar. The observation of a new cultivar during the evaluation period by nurserymen, researchers, and gardeners can do more to promote the introduction than pages of descriptive manuscript and advertisement. The enthusiasm of one horticulturist for the plant is the cheapest propaganda, and it expands into a chain-reaction response as he meets other horticulturists. The nurserymen are the crux of the program and the most influential evaluators, since during the evaluation period they may be sold on the plant and may project its potential for commercial production.

At present, the National Arboretum evaluation program consists of 90 cooperators, which include 36 nurseries, 17 arboreta and botanic gardens, 22 universities, and 15 miscellaneous. In addition to the domestic evaluation program, the new cultivars are sent to foreign countries for evaluation and promotion. Foreign distribution, which includes 14 countries, not only provides greater geographic distribution, but also enables display of plants at national and international horticultural exhibitions. Again, a foreign

EXHIBIT I

**STANDARD FORM MEMORANDUM OF UNDERSTANDING**
Between

_____
(Name of Cooperator)
And the
United States Department of Agriculture
Agricultural Research Service
For
Evaluation of Potential New Cultivars of
Ornamental Shrubs and Trees

**The Service Agrees:**

1. To supply the Cooperator with plant material for evaluation, as follows:

**The Grower Agrees:**

1. To furnish the land and labor and meet all expenses involved in planting and adequately caring for the plant material.
2. To permit representatives of the Service to make observations of these materials in the field and to obtain samples when desired.
3. Not to propagate additional plants for his own use, nor to sell, give away or otherwise distribute any part of these selections until authorized by the Service to do so.
4. To use the official name or number of the selection, or selections, assigned by the Service in all reference to such selection or selections.

**It is Mutually Agreed:**

1. No restrictions shall apply to propogation and disposal of plant material after the selection has been named and officially released by the Service.
2. That all information derived from these studies shall be jointly shared by the Cooperator and the Service.
3. This agreement supersedes existing agreements and shall apply to Service plant material already distributed to the Cooperator for testing.
4. The patent provision applicable to this agreement shall be in accordance with the statement on the reverse of this form.

The responsibilities assumed by the Service are contingent upon funds being available from which the expenditures may be met.

No member of or delegate to Congress or resident commissioner shall be admitted to any share or part of this agreement or to any benefit that may arise therefrom, unless it be made with a corporation for its general benefit.

This agreement shall become effective _____, and shall continue indefinitely but may be terminated by mutual agreement at any time.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE

_____
Name of Cooperator

By _____ _____
Name Title

_____
Address

_____

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EXHIBIT II

**INDIVIDUAL OR COMMERCIAL CONCERN**
**(7 AR 185)**

invention resulting from this cooperative work and made jointly by an employee or employees of the United States rtment of Agriculture and a cooperator or an employee or employees of a cooperator shall be fully disclosed, either by cation or by patenting in the United States. The domestic patent rights in any such United States patent shall either be ated to the free use of the people in the territory of the United States or be assigned to the Government of the United s of America, as represented by the Secretary of Agriculture. Where the domestic patent rights are assigned to the rnment, the United States Department of Agriculture shall have an option to acquire the foreign patent rights in the tion on which an application for a United States patent is filed, for any particular foreign country, said option to expire e event that the Government fails to cause an application to be filed in any such country on behalf of the Government termines not to seek a patent in such country within six months after the filing of the application for a United States nt on the invention. Where the domestic patent rights are assigned to the Government, but the foreign patent rights are ned by an employee, the employee shall grant to the Government a nonexclusive, irrevocable, royalty-free license in any nt which may issue thereon in any foreign country, including the power to issue sublicenses for use in behalf of the rnment and/or in furtherance of the foreign policies of the Government, and said license shall also include the power blicense American licensees under Government-owned United States patents to practice the invention without payment yalty or other restriction in any foreign country wherein a corresponding patent may issue to the employee or his gn assignee. Any invention made independently by an employee or employees of the United States Department of culture or by a cooperator or an employee or employees of a cooperator shall be disposed of in accordance with the y of the United States Department of Agriculture or a cooperator, respectively, provided, that in the event the invention de solely by an employee or employees of the cooperator, the cooperator shall grant or shall obtain from the assignee y patent issued on said invention an irrevocable, nonexclusive, world-wide, royalty-free license for the Government ll government purposes, and provided further, in the event the invention is made solely by an employee or employees e cooperator, that unless the cooperator or his assignee has taken effective steps within three years after a patent s on the invention to bring the invention to the point of practical application or has made the invention available for sing royalty-free or on terms that are reasonable in the circumstances, or can show cause why he should retain the ipal or exclusive rights for a further period of time, the Government shall have the right to require the granting of a se to an applicant on a nonexclusive, royalty-free basis.

award reaps free promotion through publication and press releases. International sell directly influences domestic sell.

Even though the primary objectives of the evaluation program are to get selections tested over a diverse area by a number of experts, it is not the intent that the evaluators make final selections of cultivars. Their expertise can confirm and extend the previous assessment of cultivars made during the 3 to 10 years prior to evaluation. A plant must pass through evaluation and receive favorable acceptance from a sufficient number of testers before there is additional propagation for stock increase.

## STOCK-INCREASE PROGRAM

Following evaluation and final selection, the next step in the planned introduction of a superior cultivar is stock increase. Since the emphasis is now on numbers of plants in the quickest possible time, the expertise and skills of the professional propagator are enlisted in a Cooperative Stock Increase Program.

In this program, plants of the new cultivar under code number are distributed by the National Arboretum to cooperating wholesale propagation nurseries—under a Standard Form Memorandum of Understanding for Increasing the Planting Stock of Vegetatively Propagated Plants Furnished the Nursery (Exhibit III). In this memorandum, the restrictions on patents still apply (Exhibit II). The cooperator agrees to increase stock, use the designated cultivar code, and report the number of plants propagated at the end of each growing season prior to release.

The same procedure as for the Evaluation Program is followed in completing the memorandum. From a stock block of younger plants established at the Arboretum in anticipation of stock increase, a quantity of plants must be propagated

EXHIBIT III

**STANDARD FORM MEMORANDUM OF UNDERSTANDING**
Between

_____
(Name of Cooperator)
And the

United States Department of Agriculture
Agricultural Research Service
For

Increasing the Planting Stock of Vegetatively
Propogated Plants Furnished the Nursery

**The Service Agrees:**

1. To supply the nursery planting stock for increase, as follows:

**The Nursery Agrees:**

1. To increase these stocks in accordance with sound practices.
2. To make the increase planting available for observation, and when necessary, for roguing by representatives of the Service.
3. When total planting stock of each clone is increased to _____ plants, to return _____ percentage of the stock of each as liners under 12" to the Service.
4. To use the official name or number of the cultivar or cultivars assigned by the Service in all reference to such cultivar or cultivars.

**It is Mutually Agreed:**

1. _____ percentage of the crop shall be the property of the cooperator after notification of public release by the National Arboretum of the Service, and he may dispose of his share as he sees fit, subject to other provisions of this memorandum.
2. To afford a sound basis for the announcement of available sources in the nursery trade, at the end of each growing season prior to release, the Nursery will report the amount of increase of each cultivar in his possession being increased under terms of this memorandum; and that the Service will in turn report to the Nursery the known total increase reported to be in the possession of all cooperating nurseries.
3. The patent provision applicable to this agreement shall be in accordance with the statement on the reverse of this form.

The responsibilities assumed by the Service are contingent upon funds being available from which the expenditures may be m

No member of or delegate to Congress or resident commissioner shall be admitted to any share or part of this agreement or to any benefit that may arise therefrom, unless it be made with a corporation for its general benefit.

This agreement shall become effective _____ , and shall continue indefinitely, but may be modified, amended, or supplemented by mutual agreement and may be terminated by either party upon _____ notice.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE

_____
Name of Cooperator

_____

By: _____
Name Title

_____
Address

_____

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for stock increase distribution. Usually 25 to 100 plants are shipped to each cooperator in January or February. Also, if he was an evaluator, he is instructed to obtain additional cuttings from specific evaluation plants. If his nursery is not too distant from Washington, D.C., additional cuttings may be supplied at another season. It is essential that sufficient stock be provided to enable immediate propagation. Too few initial stock plants result in a time lapse while the nurseryman produces a stock block. Annually in December, the cooperators are requested to submit data on the total number of plants propagated.

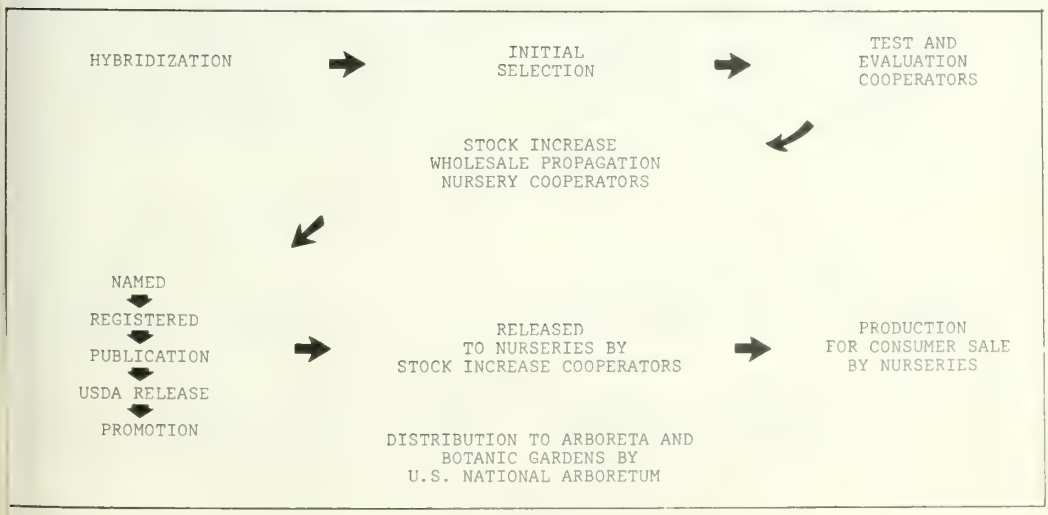
Only those nurseries that will produce liners in quantity for sale to other nurseries are an asset to a stock-increase program. A nursery that primarily propagates liners for its own production of specimen plants is of limited use in the promotion of a new cultivar. Experience has shown that it is most beneficial to rigidly restrict the number of stock-increase cooperators and to supply each with a greater number of plants—rather than have more cooperators who receive fewer plants. It is not economically feasible for a nurseryman to gear up for production and to initiate promotion of a new plant unless the numbers are in the hundreds or thousands. Likewise, the nurseryman as a shrewd businessman cannot afford to gamble on an unknown new plant. Again, the merits of a well-executed evaluation program that has "sold" the plant to the nurseryman will guarantee immediate large-scale propagation. Evaluation "sell" and stock increase must be intrinsically coordinated if a new cultivar is to be mass-propagated rapidly prior to introduction.

## CULTIVAR INTRODUCTION

The timing for naming, releasing, and promoting a new cultivar is the final step to successful introduction. Early naming and publication that are previous to an adequate supply of stock create a demand for plants that largely dissipates by the time the plants are available for sale. The immediate impact of cultivar naming and publication can be exploited by synchonization with stock availability. For shrubs that are readily propagated and sold in small sizes, the naming can be made a few years after stock increase distribution; but for trees, which are slower to propagate and sold in larger sizes, the naming will be delayed.

When a predetermined number of plants of a particular National Arboretum

Figure 1.—The U.S. National Arboretum Introduction Program.



introduction has been produced, the cultivar is named and released by the Agricultural Research Service, U.S. Department of Agriculture. The details of naming, registration, and publication have been presented in another symposium paper and thus are omitted from this discussion, but are diagramatically presented in the National Arboretum Introduction Program (fig. 1). It is only after naming and release that the plants propagated by the stock-increase cooperators may be offered for sale.

The attainment of the goal of wide acceptance by the nursery trade and the public can be expedited by effective promotion. In order to further "sell" the new cultivar to other nurserymen, brief, factual information is released to the trade journals. In the meantime, the plants in evaluation and demonstration plantings have matured and continue to promote "sell" to the public. The distribution by the National Arboretum to cooperating arboreta, botanic gardens, and research institutions further encourages public demonstration plantings. When the cultivar is listed in nursery catalogs, the Information Division of the Agricultural Research Service distributes press releases to further publicize the new cultivar.

The National Arboretum Introduction Program, with its many ramifications, has proved an effective procedure for the promotion "sell" and introduction of new plants from the diverse shrub- and tree-breeding projects. The experiences of the past decade have evolved into a planned program, which in its entirety or in part could be a model for utilization by other research institutions.

## SUMMARY

Briefly, the current procedure of cultivar introduction into the nursery trade, and subsequently to the consumer, is as follows:

1. Research involving hybridization, seedling production, testing, and initial selection is conducted at the U.S. National Arboretum.

2. The selected plant is propagated and sent to cooperators in other geographic regions for evaluation under a Standard Form Memorandum of Understanding for Evaluation of Potential New Cultivars of Ornamental Shrubs and Trees.

3. Propagation stock of the plant selected for introduction is distributed under code number to cooperating wholesale propagation nurseries for volume stock increase under a Standard Form Memorandum of Understanding for Increasing the Planting Stock of Vegetatively Propagated Plants Furnished the Nursery.

4. The selection is given a cultivar name that is registered and published, and official release is made by the Agricultural Research Service, U.S. Department of Agriculture.

5. After stock increase, publicity in the form of brief factual information is released by the National Arboretum to the trade journals.

6. The cultivar is released for distribution by cooperating wholesale propagation nurseries to other wholesale and retail nurseries.

7. The cultivar is distributed by the National Arboretum to cooperating arboreta, botanic gardens, and research institutions.

8. When a cultivar is listed in at least three retail nursery catalogs, the Information Division of the Agricultural Research Service distributes press releases to publicize the merits and the availability of the cultivar to the consumer.

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# THE CHALLENGE: AN INDUSTRY TOGETHER

*by* ROBERT F. LEDERER, *Executive Vice President, American Association of Nurserymen, 230 Southern Building, Washington, D.C. 20005.*

*ABSTRACT.* The allied landscape industry encompasses more than a marketing chain from nurseryman to consumer: it is a chain with many links. One link is the research community that seeks to develop trees and other plants for a variety of landscape uses. The need for cooperation and communication throughout the industry is emphasized.

A NEW MARKETING CONCEPT, developed 5 years ago by the American Association of Nurserymen, has become known as *Green Survival.* When we sat down to outline just exactly what this program would be, we knew we had to have a position paper, and that that paper had to be concerned with the various functions of plant material.

One of the first things we did to explain Green Survival to our various publics was to create a slide-and-sound presentation. As we look at that production now, we see that, just 5 years ago, our minds and our imaginations produced a really limited number of ideas about how plants affect the environment. Our presentation to condition the viewer's mind to accept plants as a contribution to his environment bore heavily on other aspects where our connection is limited—water pollution, litter, and so on.

A few months ago we introduced a new Green Survival audio-visual presentation that deals exclusively with the things that plants can do to improve our environment. This program strongly reflects how our emphasis has changed in a very short time. Today the Green Survival story talks about actually selecting plant material for its capabilities in noise abatement, or specifically to be used in screening, or in reducing gaseous and particulate matter from the atmosphere, or in modifying microclimates, or in just being around us, contributing to our mental stability.

What a long way all of us have come in a short time!—all of us in what we call "the allied landscape industry".

Not very long ago I looked at this industry of ours as an entity that started with the grower and ended with the consumer. I was wrong. And if anyone in this room thinks that anything starts or ends in him, he is wrong; and I hope he will join me in a very great changing of the mind.

It may be too simple an explanation to look at this industry as a chain—an endless one which, if we follow it link for link, will lead us back to the beginning. And

each of us in that chain—research scientist, producer, seedsman, plant propagator, landscape firm, retail firm, salesmen at all levels, regulatory personnel, educator, maintenance man, arborist, legislator, planner at one of the levels of government, architect, trade and consumer press, supplier—has only a very short-term interest in any particular plant. If we are furnishing containers to the industry, the container we sell will have a functional use to the plant for a terribly short time. A grower who may hold a shade tree for 8 to 10 years has an interest in that plant for a relatively short time. A plant breeder who discovers a plant that has commercial application makes his contribution quickly in relation to the long period of the life of all of the plants that will be propagated as a result of his creation.

No matter where you start in the endless chain that describes this industry, and no matter in which direction you move, you will find each link dependent on the one before and the one after. We have a great advantage as an industry—we are friends. We are deeply interested and involved with the links on the chain closest to us; and as we developed in these past few years, our interest and understanding of links of the chain farther and farther removed has become stronger and stronger. I defy anyone to show that any link of our chain is separate from the industry or that one link is more important than the others. I must argue with those who, through word of mouth or printed word, try to separate us. We depend on each other.

## IMPORTANCE OF LANDSCAPE INDUSTRY

Our market for nursery products is growing tremendously. In 1965-66 the Horticultural Research Institute, an independent research organization with offices in Washington, D. C., determined that the retail market for nursery products amounted to about 1.6 billion dollars. Five years later, in 1970-71, that figure had grown to 2.1 billion dollars, and it is our estimate that right now the market for nursery products at retail amounts to 3 billion dollars. That is big business, and much of it has been made possible by research. But in my opinion, we haven't seen anything yet—IF we really begin to apply ourselves in a business-like manner to the market.

I know it is a little alien to many involved in research to think in terms of the market place, but let me tell you that with the limited dollars available for research, we must apply ourselves to those research efforts that offer the greatest opportunity to provide new products and services to the customer. Not only do I urge you as researchers to aim at the consumer in your research efforts, but I urge you to begin to give serious thought to the quickest way there. And the way to start is by knowing what is needed and, as you move toward final development, by sharing your knowledge along the way with those who can best use it.

One of the most serious problems in our chain is communication between the various links. I have been close to the nursery industry for 17 years. I know thousands of nursery businessmen. I have been close to the research community for nearly that long, and I know dozens of research scientists. All of the nursery businessmen I know need the results of the efforts of all of the research scientists I know. In order to be properly oriented, research scientists need the opinion of the nursery businessmen.

But I ask you: How often do the two get together? When you come up with results, often they are held back waiting for publication in a scientific journal where your credits as a scientist can be made. Often good usable results never arrive at that point where they can be put into operation, because people who can use them are certainly not those who read your scientific journals. We need a compromise. Certainly, you have the right to gain recognition in your particu-

lar sphere of the allied landscape industry; but, certainly, the industry has a right to be able to take advantage of your efforts quickly. *Publish or perish,* I guess, is here to stay. However, I urge you to publish in a way that the results of your efforts won't perish, but rather will be used as stepping stones toward a better product for the consumer.

The primary goal of the Horticultural Research Institute is to serve as a communications link between the research community and those who take your developments and move them on to the final consumer. The Institute's grant program, its various publications, its new Horizon's Day at our annual convention, are all aimed at trying to become an entity through which researchers will be willing to funnel information to the nursery industry. Both the American Association of Nurserymen and the Horticultural Research Institute are deeply interested in helping industry work with government.

For decades our organization testified each year against the plant-production programs of the Forest Service. Along came a single individual many of you knew—Dick Lane, who was dedicated to teaching us how we could cooperate with the Forest Service, and the Forest Service with us. He set up a relationship between us that exists to this day, and it has created tremendous good for both of us. Whether we liked it or not, we suddenly found out that we knew a great deal about Forest Service research. Through my chairmanship of the Northeastern Forest Research Advisory Committee, visits to Forest Service laboratories, and personal exchanges with scientists, we became big supporters of their activities—all thanks to one interested individual.

## COOPERATION AND COMMUNICATION

For a good many years now we have grasped every branch of cooperation held out to us by government. Service on the Arboretum Advisory Committee by nursery businessmen, symposiums like this one, the recent meetings held with scientists of the Agricultural Research Service—all have been big steps in improving communications all the way along the chain. The arborists, the growers, the landscape contractors, the seedsmen, and the architects all meet on a regular basis to exchange information on what each segment of the industry is doing. These meetings are relatively new and are effective in communicating between other links of the chain. It is all so easy when the effort is made, and that effort depends on a few people, many of them participants in this symposium.

All of us in our nursery industry chain are dedicated to furnishing the best possible product to our customer, and the only way that can be done is through all of us working together. We must get better at telling you what that customer needs, and you must get better at listening. When you develop your research program, keep very much in mind that your inclination may be to develop projects that are of most interest to you. Overcome that inclination. Base your projects on what will be of most practical value to producing better products, better chemicals, and better plants for our customer, because we are all urban farmers with a practically untapped market waiting for our products. Nurseries are not research institutions. Just as you must publish or perish, they must profit or perish. Certainly, many nurseries have achieved significant research results, but in the long run we must depend on you because you have the time, the money, the land, and the labor necessary for making a broad approach to the development of better trees and shrubs and chemicals.

Because we have such a virgin market before us, we surely do not need that part of the market that is involved in selling nursery stock to replace trees that have failed because of some inherent weakness to the stresses imposed by nature or Man. We want and need products we can guar-

antee will become established easily and will last for decades. To do that will require the cooperation of us all, beginning, in this instance, with the geneticist and breeder who is spending his days building the trees and shrubs of tomorrow. Pathologists, entomologists, physiologists, and every other specialist must play an important part in this building. And as you build—communicate.

The American Association of Nurserymen is in constant communication with 1,200 growers, 1,300 landscape firms, and 1,300 retailers. There is a lot of practical knowledge in our constituency, but I do not remember ever being asked to survey our members as prelude to developing a research project. They have occasionally been questioned in the course of various studies; but, as far as I know, their opinions and needs have not been sought in the planning of the research. I ask you: Why work in a vacuum? If your goal is to develop a fine Norway maple, the place to start may very well be by asking the municipal arborist or forester or all of our northern growers to share with you the best Norway maple they know of. He can take you to it right away: he has been watching it for years, but nobody ever asked him about it. Certainly, it may turn out that it was "planted over a dead horse", but on the other hand, it may turn out to be a way of saving 50 years of development simply by communicating.

## CONCLUSION

In closing, let me urge you that, for the good of all of us and for the good of those we serve, each of us look backward and forward at the links of the chain, behind and ahead of us, to see what is really needed and to map out a plan of research for the future that relates to need above all other considerations.

It all depends on communication.

---

Northeastern Forest Experiment Station.
1976. **Better trees for metropolitan landscapes: symposium proceedings.** Northeast. For. Exp. Stn., Upper Darby, Pa.
256 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-22)

A report on the symposium held 4-6 November 1975 at the National Arboretum, Washington, D.C., containing 29 papers on selection of trees for metropolitan environments; selection strategies of planners, growers, and breeders; and putting new cultivars into use.

273 + 165.4--(082)

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